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FLAME TEST VEHICLE 1976 FLIGHT TEST SERIES

Aerojet Liquid Rocket Company
P.O. Box 13222
Sacramento, California 95813

February 1977

Final Report

Contract No. DNA 001-74-C-0266

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Prepared for:

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The FLAME vehicle was designed as an inexpensive test vehicle to subject various reentry nosetip experiments to ICBM-type reentry environments. The vehicle is a two-stage solid rocket that is dropped from an F-4 aircraft, allowed to coast for a predetermined time, and then fired toward earth at a predetermined angle, thus reaching the experiment environment at the end of second-stage burn.

Two such test flights took place in early 1976 at the Tonopah Test Range, placing the total number of flights to date at eight. over

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Report Documentation Page (cont.)

20, Abstract (cont.)

The vehicle performed as expected on all but two flights; the first stage motor in each case experiencing a nozzle failure. The failure mode was ultimately corrected with the last two flights being successful.

The test results indicate the vehicle has met all its objectives relative to performance, versatility, quick reaction, and low cost.

SUMMARY

The FLAME vehicle was designed as a test vehicle to subject various reentry nosetip experiments to ICBM-type reentry environments. The vehicle is a two-stage solid rocket that is dropped from an F-4 aircraft, allowed to coast for a predetermined time, and then fired toward earth at a predetermined angle, thus reaching the experiment environment at the end of second-stage burn. Figure 1 is a photograph of Vehicle S/N 007 with the F-4J shortly after takeoff at the Naval Weapons Center, China Lake, California.

The FLAME concept was developed to provide a low-cost test vehicle which would have flexibility in launch and would require a minimum of range real estate. Use of the aircraft as a launch platform provides the required flexibility and permits launches to be conducted at a variety of sea or land ranges and in all types of weather conditions which would preclude ground-launch test vehicles.

A drop test vehicle was flown at the Tonopah Test Range, followed by eight live firings; two over Wallops Island Range and six at the Tonopah Test Range.

This report effort concerns itself with the launch of Vehicles 07 and 08. It also addresses several design changes that were made prior to these flights.

A detailed description of the FLAME vehicle design, fabrication, field operations, and test results of the drop vehicle and the first six flights are contained in DNA Report No. DNA3836F, "FLAME Test Vehicle Program".

The preliminary design of an optimized FLAME (Super FLAME) vehicle to meet the desired performance criteria is presented in Appendix D.

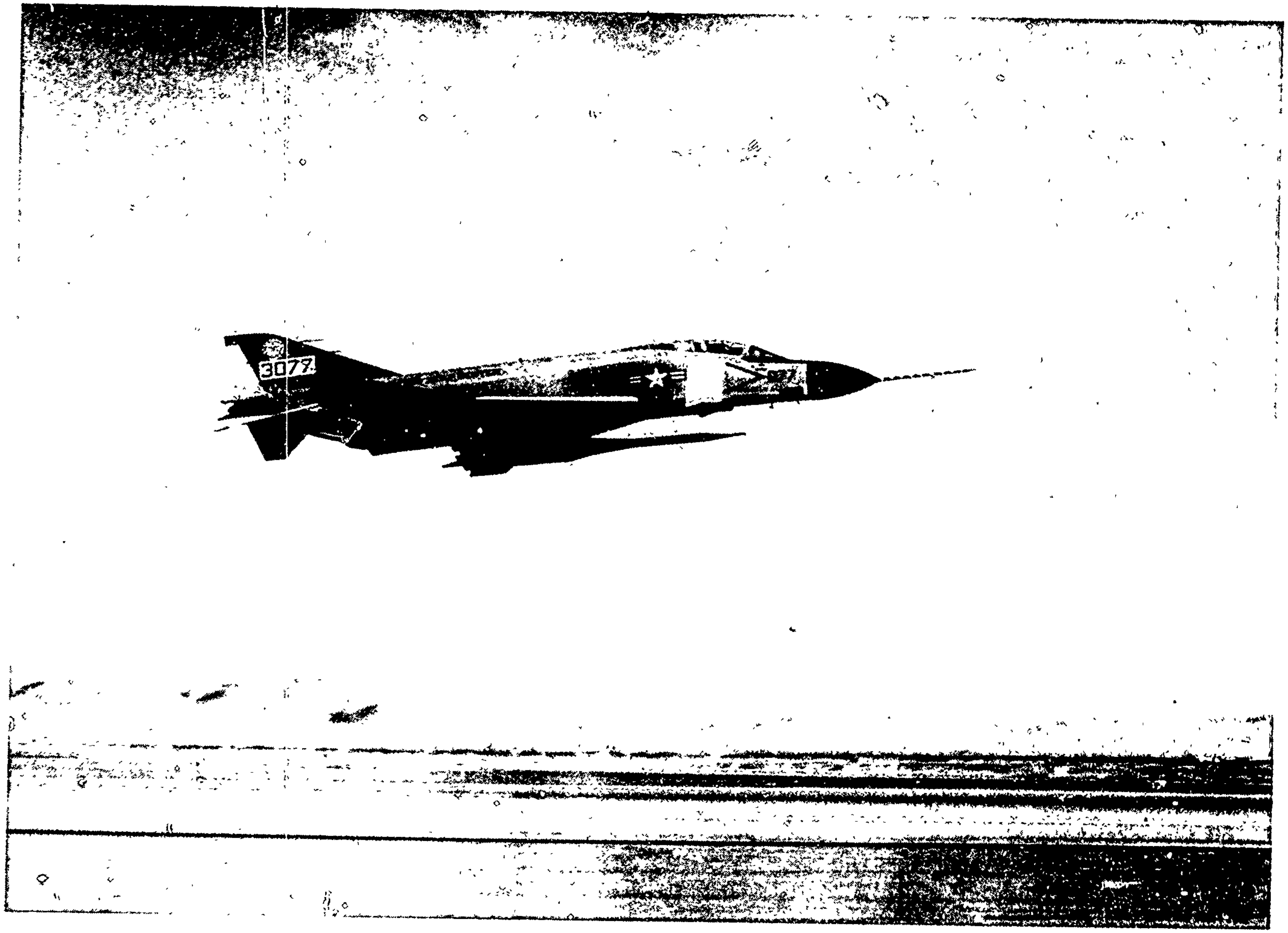

Figure 1. FLAME Flight 07, China Lake

Conversion factors for U.S. customary
to metric (SI) units of measurement.

To Convert From	To	Multiply By
angstrom	meters (m)	1.000 000 X E -10
atmosphere (normal)	kilo pascal (kPa)	1.013 25 X E +2
bar	kilo pascal (kPa)	1.000 000 X E +2
barn	meter^2 (m^2)	1.000 000 X E -28
British thermal unit (thermochemical)	joule (J)	1.054 350 X E +3
calorie (thermochemical)	joule (J)	4.184 000
cal (thermochemical)/cm^2	mega joule/m^2 (MJ/m^2)	4.184 000 X E -2
curie	giga becquerel (GBq)*	3.700 000 X E +1
degree (angle)	radian (rad)	1.745 329 X E -2
degree Fahrenheit	degree kelvin (K)	$t_K = (t^\circ f + 459.67)/1.8$
electron volt	joule (J)	1.602 19 X E -19
erg	joule (J)	1.000 000 X E -7
erg/second	watt (W)	1.000 000 X E -7
foot	meter (m)	3.048 000 X E -1
foot-pound-force	joule (J)	1.355 818
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 X E -3
inch	meter (m)	2.540 000 X E -2
jerk	joule (J)	1.000 000 X E +9
joule/kilogram (J/kg) (radiation dose absorbed)	Gray (Gy)**	1.000 000
kilotons	terajoules	4.183
kip (1000 lbf)	newton (N)	4.448 222 X E +3
kip/inch^2 (ksi)	kilo pascal (kPa)	6.894 757 X E +3
ktap	newton-second/m^2 (N-s/m^2)	1.000 000 X E +2
micron	meter (m)	1.000 000 X E -6
mil	meter (m)	2.540 000 X E -5
mile (international)	meter (m)	1.609 344 X E +3
ounce	kilogram (kg)	2.834 952 X E -2
pound-force (lbf avoirdupois)	newton (N)	4.448 222
pound-force inch	newton-meter (N·m)	1.129 848 X E -1
pound-force/inch	newton/meter (N/m)	1.751 268 X E +2
pound-force/foot^2	kilo pascal (kPa)	4.788 026 X E -2
pound-force/inch^2 (psi)	kilo pascal (kPa)	6.894 757
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 X E -1
pound-mass-foot^2 (moment of inertia)	kilogram-meter^2 (kg·m^2)	4.214 011 X E -2
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.601 846 X E +1
rad (radiation dose absorbed)	Gray (Gy)**	1.000 000 X E -2
roentgen	coulomb/kilogram (C/kg)	2.579 760 X E -4
shake	second (s)	1.000 000 X E -8
slug	kilogram (kg)	1.459 390 X E +1
torr (mm Hg, 0° C)	kilo pascal (kPa)	1.333 22 X E -1

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials.

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A. GENERAL

1. FLAME CONCEPT

The FLAME (Fighter Launched Advanced Material Experiment) Program was initiated to provide more realistic test data relative to erosion effects of reentry nosetips. The specific FLAME program objective is to collect coupled erosion/ablation data derived from reentry vehicles traversing a measured hydrometer environment under specific reentry conditions. These data will be utilized to assist in the material selection and in establishment of design concepts for future reentry vehicle development programs. This program is coordinated with the HEART and the SAMS programs as a portion of the overall ABRES program of the U.S. Air Force.

The FLAME concept was pursued because of its versatility in adapting nosetips, its response time relative to lead time requirements before launch, its versatility relative to launch conditions and locations, and its cost effectiveness.

2. FLAME VEHICLE PROGRAM

a. Vehicle Constraints

The FLAME vehicle was launched from a Navy F-4J aircraft at a predetermined drop condition that allows the nosetip to enter the desired test environment under the desired conditions. The vehicle was designed to be capable of subjecting a 50-lb payload (nosetip with appropriate instrumentation and recovery system) to a reentry trajectory with the following parameters:

(1) ~15,000 fps at 32,000 ft
(2) Launch over Wallops Island Range
(3) Launch from an F-4J aircraft

A, 2, FLAME Vehicle Program (cont.)

During the program, however, the above criteria was revised to the following due primarily to revised data relative to aircraft and rocket performance:

(1) 13,250 fps at 38,000 ft at a gamma of 18.25°

(2) Launch over Wallops Island Range and Tonopah Test Range

(3) Launch from an F-4J aircraft

The vehicle was also required to withstand the environmental conditions associated with being stored under the aircraft in inclement weather.

To meet the above, the aircraft flight profile at drop is:

(1) 55,000 ft altitude

(2) 30° up gamma

(3) Mach 1.3 (based on true air speed)

The following table describes the vehicle nosetip configuration in addition to pertinent dates and launch range:

TABLE 1

FLAME VEHICLE LAUNCH DATA

Vehicle S/N	Launch Range	Nosetip	Vehicle Delivery	Launch Date	Other
Drop Test	NATC/TTR	N/A	08-22-74	10-09-74	Timer Ign.
01	WI	Carbon-Phenolic	09-17-74	02-04-75	Timer Ign.
02	TTR	Carbon-Phenolic	02-19-75	02-27-75	Command Ign.
03	WI	Hi Ox Fineweave	02-27-75	03-28-75	Command Ign.
04	TTR	Tungsten (Segmented)	03-13-75	04-18-75	Command Ign.

A, 2, FLAME Vehicle Program (cont.)

TABLE 1 (cont.)

Vehicle S/N	Launch Range	Nosetip	Vehicle Delivery	Launch Date	Other
05	TTR	Tungsten (Solid)	04-01-75	06-03-75	Command Ign. Beacon
06	TTR	Transpiration Cooled (Gas)	04-21-75	06-04-75	Command Ign.
07	TTR	Carbon/ Carbon (Low Trim)	01-06-76	01-22-76	Command Ign.
08	TTR	Transpiration Cooled (Gas)	01-06-76	01-26-76	Command Ign.

Figure 2 illustrates the FLAME vehicle Major Milepost Schedule as accomplished.

B. VEHICLE DESIGN

1. GENERAL

The FLAME system was designed to be carried under a fighter-type aircraft which would have the capability of dropping the missile at a variety of altitudes, pitch elevations, and Mach numbers. A survey of available aircraft in inventory led to the selection of the F-4J. Other available aircraft studied were limited either by performance or by ground clearance geometry or availability. A program ground rule was to utilize an aircraft directly from inventory without modification. The F-4J utilized in this program uses a LAU-77 standard missile launcher affixed to the AERO-27 bomb rack carried internal to the aircraft. The LAU-77 has the attach lugs offset 4 degrees to provide clearance from the nose wheel by the missile payload. Electrical connections to the cockpit are through the standard 28-pin line available at the external stores rack. A safe and arm control box was provided in the cockpit.

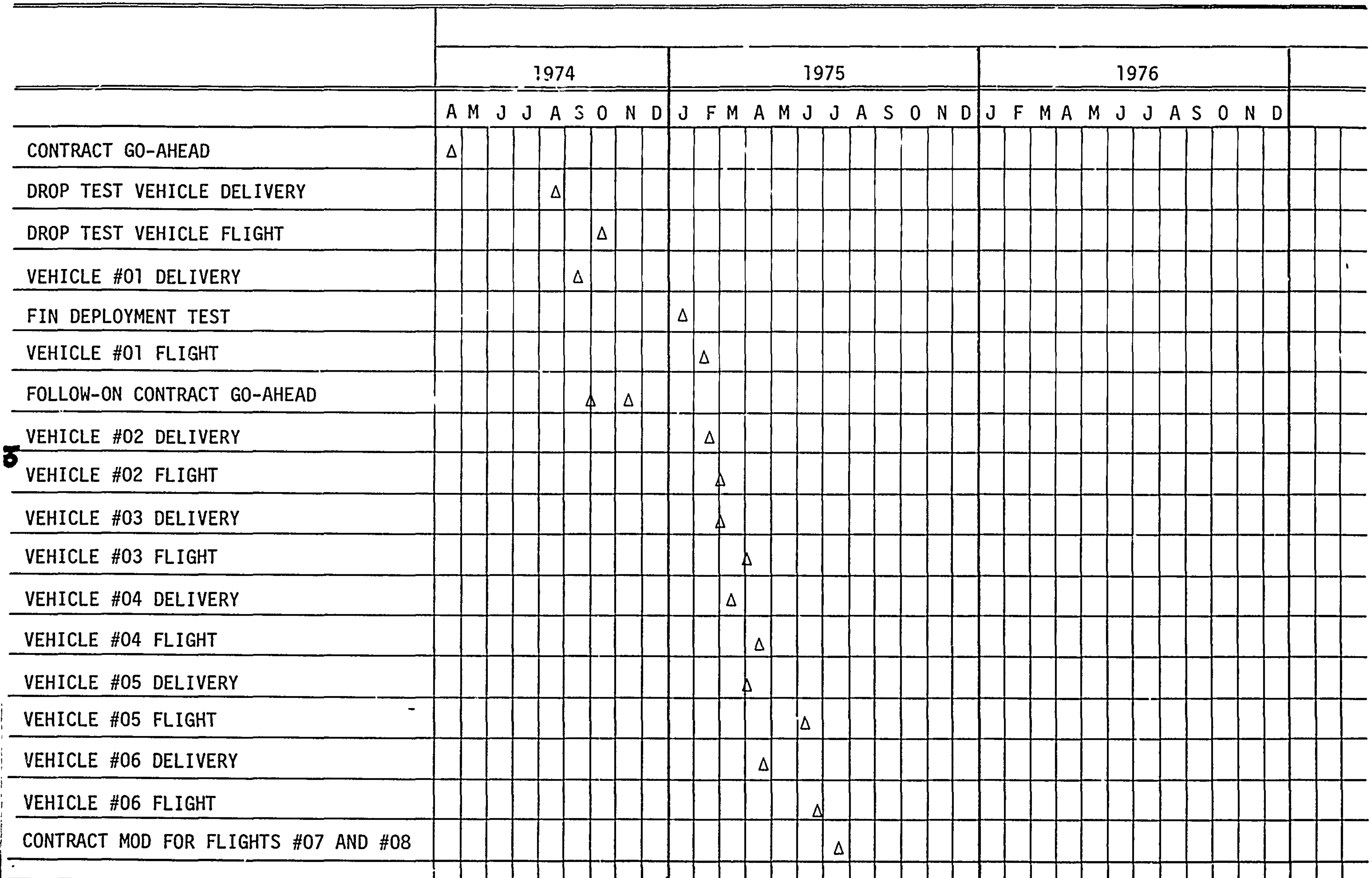

Figure 2. FLAME Vehicle Program Schedule

Figure 2 (cont.)

	1974									1975												1976											
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
VEHICLE #07 DELIVERY																						Δ											
VEHICLE #07 FLIGHT																						Δ											
VEHICLE #08 DELIVERY																						Δ											
VEHICLE #08 FLIGHT																						Δ											

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B, 1, General (cont.)

No modifications to the aircraft or other aircraft subsystems were required for this program.

The TX261-3 Pedro was selected for the first stage and the TE29-1A Recruit for the second stage. An extensive survey of existing rocket motors was made to determine the best staging to achieve maximum velocity and aerodynamic stability, and still fit aircraft clearance limitations. The availability of the selected motors from Government inventory was also a consideration. The current configuration is not the optimum that could be designed within the available envelope; however, development of new motors would be required to achieve additional performance.

The FLAME vehicle was designed to be fin stabilized through first-stage burning and flare stabilized through second-stage burning. Analyses showed that the fins required for first-stage stabilization would not fit in the required clearance envelope under the aircraft. Several alternate methods of reducing the apparent fin profile were studied. These included hinged, telescoping, folding, and rotating fin concepts. The results of this design study indicated a rotating fin concept with 2 fins fixed and 2 fins rotating 69° was the most efficient from a weight and mechanical simplicity point of view. The rotating fins were affixed to ring assemblies in the tail can. Rotation was to take place 1/2 sec after release from the aircraft. Elastic shock cord was originally considered to provide the rotating energy; however, tests revealed that the shock cord was inadequate under the low temperature conditions occuring during aircraft flight.

A pneumatic piston assembly for fin deployment was designed to replace the shock cord and was successfully flown without incident. The design includes safety locks, a redundant actuation assembly, and terminal shock absorbers to preclude system damage.

B, 1, General (cont.)

The second stage is stabilized by a 6° conical flare. This design is unique, in that the flare extends considerably forward of the aft motor attachment. A weight/drag/performance trade-off analysis was conducted. Results indicated that the 6° flare provided substantially better performance than the shorter 9° flare originally considered. The flare assembly is fabricated from fiberglass and is foam-filled after assembly on the motor. The foam provides stiffness and structural stability.

The FLAME vehicle is released from the aircraft by two bomb shackles and four ejection pistons which are actuated by explosive cartridges. The fin assembly actuation system operates 1/2 sec after release. The firing system is safed until both the timer lanyard is pulled at aircraft separation and the fin deployment lock is actuated. This precludes firing of the rocket with the fins in the undeployed position.

Two first-stage ignition techniques have been employed. The initial flights were fired by an on-board timing system. Subsequent flights incorporated a command receiver. On command receiver flights, a command arm signal was given 20 sec after drop from the aircraft. The fire signal was transmitted at a time based on the desired trajectory and aircraft drop parameters as determined by real-time radar display. An attempt was made to do this automatically for Flights 07 and 08.

First-to-second-stage attachment and separation is by means of a threaded blow-out diaphragm commonly in use on several sounding rocket systems.

Payload separation is achieved by means of a specially designed manacle clamp, similar to those used on Aerobee and Astrobee rockets. It was determined that the β of the separated payload and the expended second stage are nearly identical while the payload is in the near proximity of the stage. At the extremely high Q's (dynamic pressure) (65,000 lb per square foot) occurring at the point of separation, it was determined that normal separation systems would be ineffective. Accordingly, a drag finger assembly was designed into the payload interface (on the vehicle side). Six drag plates are actuated at the time of manacle clamp deployment. These are erected by spring force normal to the flow field, thus providing the required differential drag to insure payload separation.

The high Q reentry flight environment required that second-stage ignition and payload separation be initiated prior to burnout of the preceding stages in order to obtain maximum velocity. Dual-mode pressure switches were installed on both the Pedro and Recruit motors. These switches were set to arm upon motor pressurization and fire during tail-off when chamber pressure reaches a level equivalent to zero g's. This system precludes the substantial loss of velocity that would normally occur during motor tail-off.

The thermal protection requirements for the FLAME vehicle are substantially greater than that for other sounding rockets whose normal flight mode is directed upward. An evaluation was made of the thermal and dynamic characteristics of several ablative coatings. Firex RX-2376A was selected for the FLAME application. This is a polyurethane coating which maintains a back-wall temperature of approximately 280°. It has been used successfully on the Astrobee vehicles. One of the distinguishing characteristics of Firex is a better-than-average performance in a high shear environment. Firex is applied by normal spraying techniques.

The FLAME vehicle is shown in Figure 3.

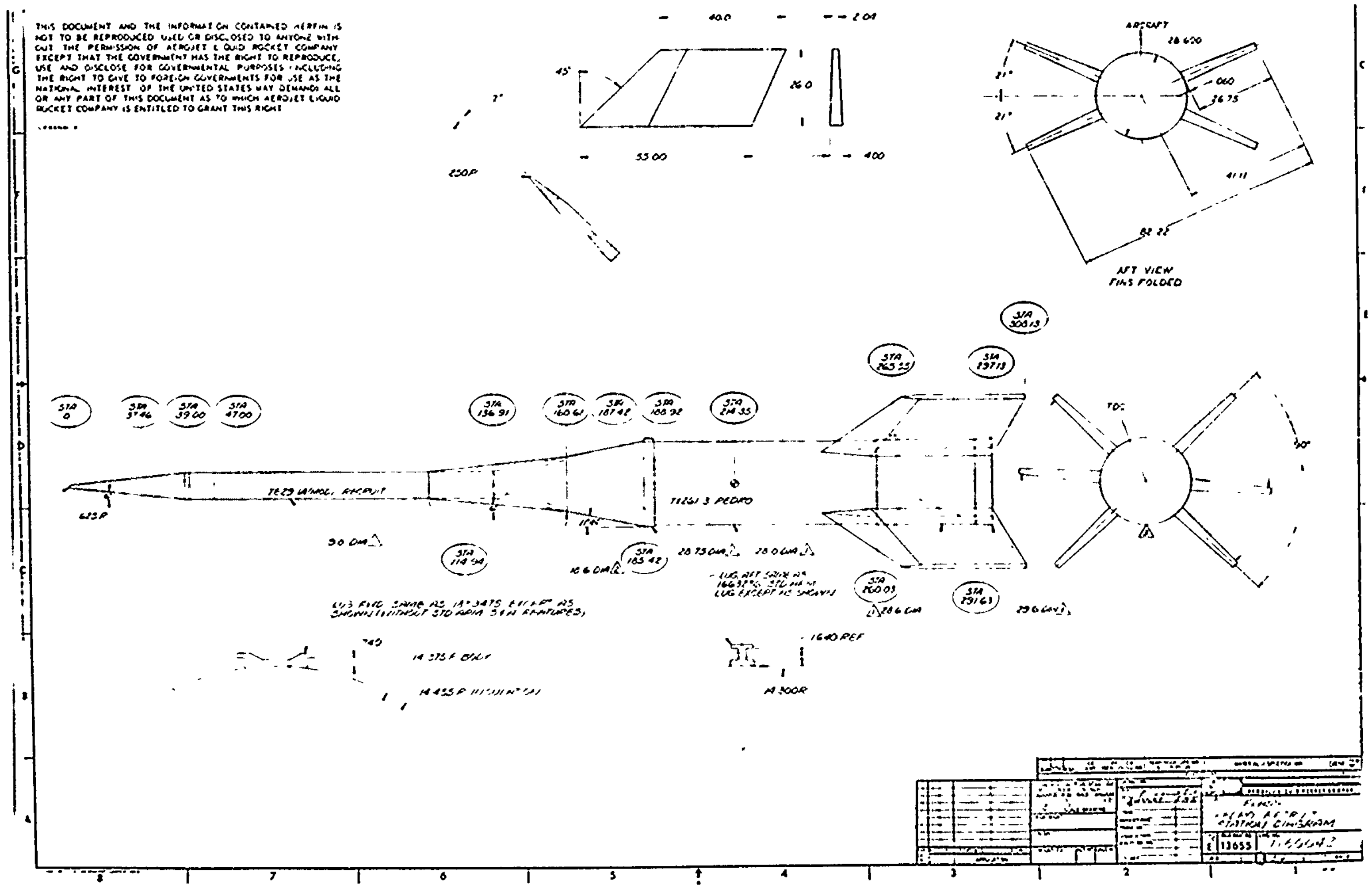


Figure 3. FLAME PEDRO Recruit Station Diagram

B, Vehicle Design (cont.)

2. WEIGHT BREAKDOWN

TABLE 2

FLAME VEHICLE WEIGHTS SUMMARY

		Loaded		Empty	
		Wt	cg	Wt	cg
1.	PAYLOAD				
	Experiment	77	19		
	Coupling Ring	1.6	38		
		78.6	19.46		
2.	FWD SKIRT				
	Skin	3			
	Rings (2)	4			
	Separation	7			
	Electronics	2			
	Bolts	1			
	Insulation	6.2			
		23.2	41		
3.	RECRUIT	362.7	94.27	92.4	106.59
	Insulation	42.7	81.0		
		405.4	93.61		
4.	FLARE				
	Ring, Fwd	2.0	137.2		
	Ring, Skirt	3.5	116		
	Mag. Skirt	6.8	150.1		
	Glass Skirt	9.6	140.4		
	Ring, Aft	6.3	159		
	Insulation	24.4	140.4		
	Foam	13.4	138.6		
	Bolts	1.0	137.2		
		67.0	141.78	42.6	141.90
	2ND STAGE TOTAL	495.6			
	2ND STAGE WITH PAYLOAD	574.2	86.64	218.6	81.82

B, 2, Weight Breakdown (cont.)

TABLE 2 (cont.)

		Loaded Wt	Loaded cg	Empty Wt	Empty cg
5.	INTERSTAGE				
	Structure & Command System	43.7	174.3		
	Diaphragm	9	160.6		
	Electronics	6	161.5		
	Adapter	20	187.4		
	Lug	6	187.4		
	Bolts	2	188		
		86.7	176.24		
6.	PEDRO	2870	229	523	239
	Insulation	30.7	223.9		223.9
	Aft Lug	2	265		
		2902.7	229.01		
7.	TAIL STRUCTURE	130	275		
	Insulation	18.9	275		
		148.9	275		
8.	FINS	220	290		
	1ST STAGE TOTAL	3358.3	232.84		
	VEHICLE TOTAL	3932.5	213.51	1413	191.51

3. FIRST STAGE MOTOR NOZZLE

A major design change was made by Thiokol to the Pedro nozzle after the completion of the failure analysis of Flight 04 and 06 failures. Results of the analysis indicated a catastrophic failure, associated with the nozzle, took place on both flights (the only vehicles using newly manufactured nozzles) shortly before burnout.

B, 3, First Stage Motor Nozzle

Retrieval of nozzle fragments from the test range was accomplished and they were examined for possible failure modes. Nothing obvious came from this examination, however. The most probable failure mode was eventually identified as having to do with the melting point of adhesive used to bond in the throat insert.

The nozzle was redesigned and static-fire tested. The test results indicated an adequate nozzle design. The redesigned nozzle (see Figure 4) is identified on Thiokol Drawing No. R53149 for a TX261-5 motor assembly.

The redesign included requirements associated with a motor propellant change for the optimized FLAME vehicle as discussed in Appendix F.

As a part of this effort, the design of the tail structure aft skirt was changed to negate the possibility of its putting side loads into the nozzle. This was accomplished by slitting the flair portion into a petal arrangement to reduce its structural rigidity. The gaps were then filled, after installation, with a pliable silicon adhesive (RTV-732) to stop any flame recirculation problems.

4. THERMAL CONTROL

Upon recovery of the S/N 04 and S/N 06 vehicle fragments from the range (reference Nozzle Failure Analysis), it was determined that the thermal design should be reexamined for local heating. Although no failures occurred, it was observed that the thermal control was inadequate in areas of turbulent interference around protuberances such as launch lugs, etc.

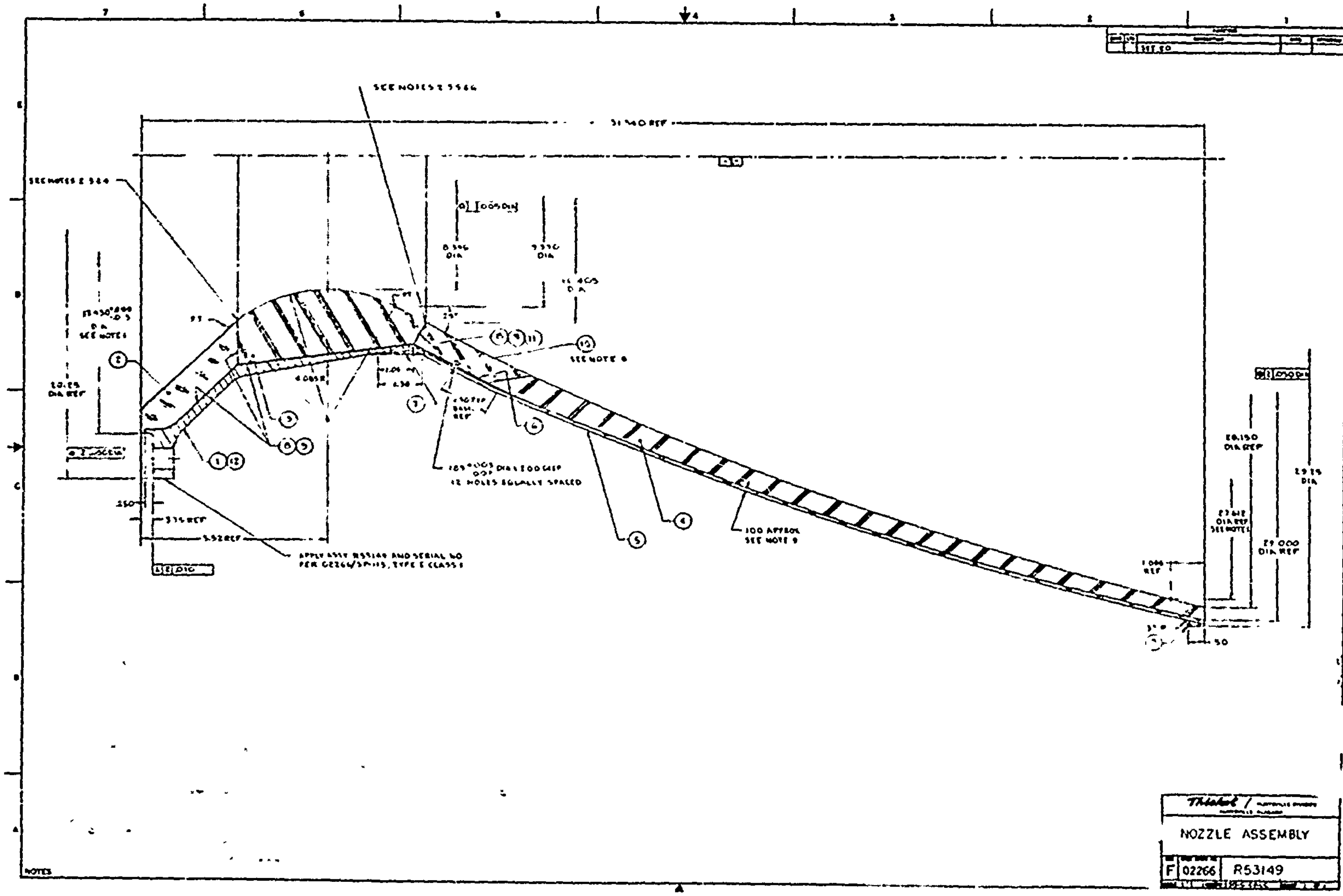


Figure 4. Nozzle Assembly - R53149

The redesign included phenolic shields placed around the forward lug and phenolic cork over the Pedro motor case/tail structure interface. In addition, the portion of the aft lug in the airstream was aerodynamically swept. The changes are shown in Figure 5.

C. FIELD OPERATIONS

Successful vehicle flights were conducted at the NASA/Wallops Flight Center and the Sandia/Tonopah Test Range (TTR). Aircraft support was provided by the U.S. Navy/Patuxent River Air Station. For Wallops flights, aircraft assembly and loading took place at Patuxent River. For TTR flights, missile assembly and aircraft loading were accomplished at the Naval Weapons Center at China Lake.

A dummy vehicle was fabricated and provided to Patuxent River for flight trials prior to the actual live mission attempts. The aircraft has successfully performed several landings and take-offs and a variety of maneuvers with the FLAME vehicles. The vehicle is stressed for 6-g maneuvers; however, aircraft operations have normally been restricted to 3-g maneuvers with the FLAME installed. A typical flight profile is shown in Figure 6. The aircraft makes an in-run at a high Mach number under the control of ground radar. At the appropriate point, a pull-up command is given the pilot who maintains a steady 2-g pull-up to a flight path angle of 30°. An altitude Mach number flight gamma box is marked on the radar plot board. When the aircraft moves through any portion of this box, the controller gives a drop signal to the pilot who releases the missile and returns to base. The missile coasts over apogee at approximately 61,000 ft and is fired on the down leg to simulate reentry conditions. Burnout is normally programmed to occur between 35,000 and 40,000 ft; however, a

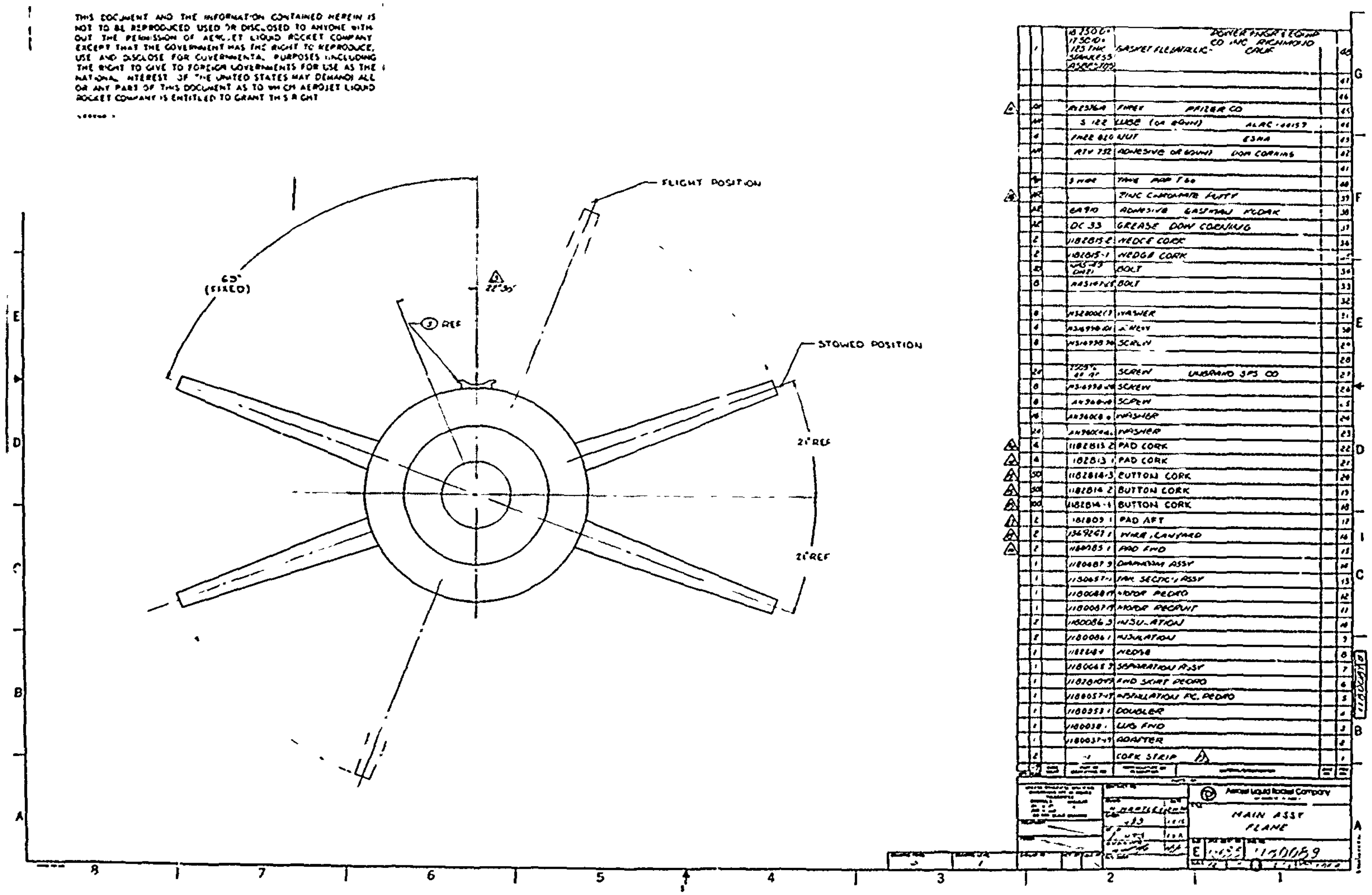


Figure 5. Main Assembly, FLAME - 1180089 (Sheet 1 of 4)

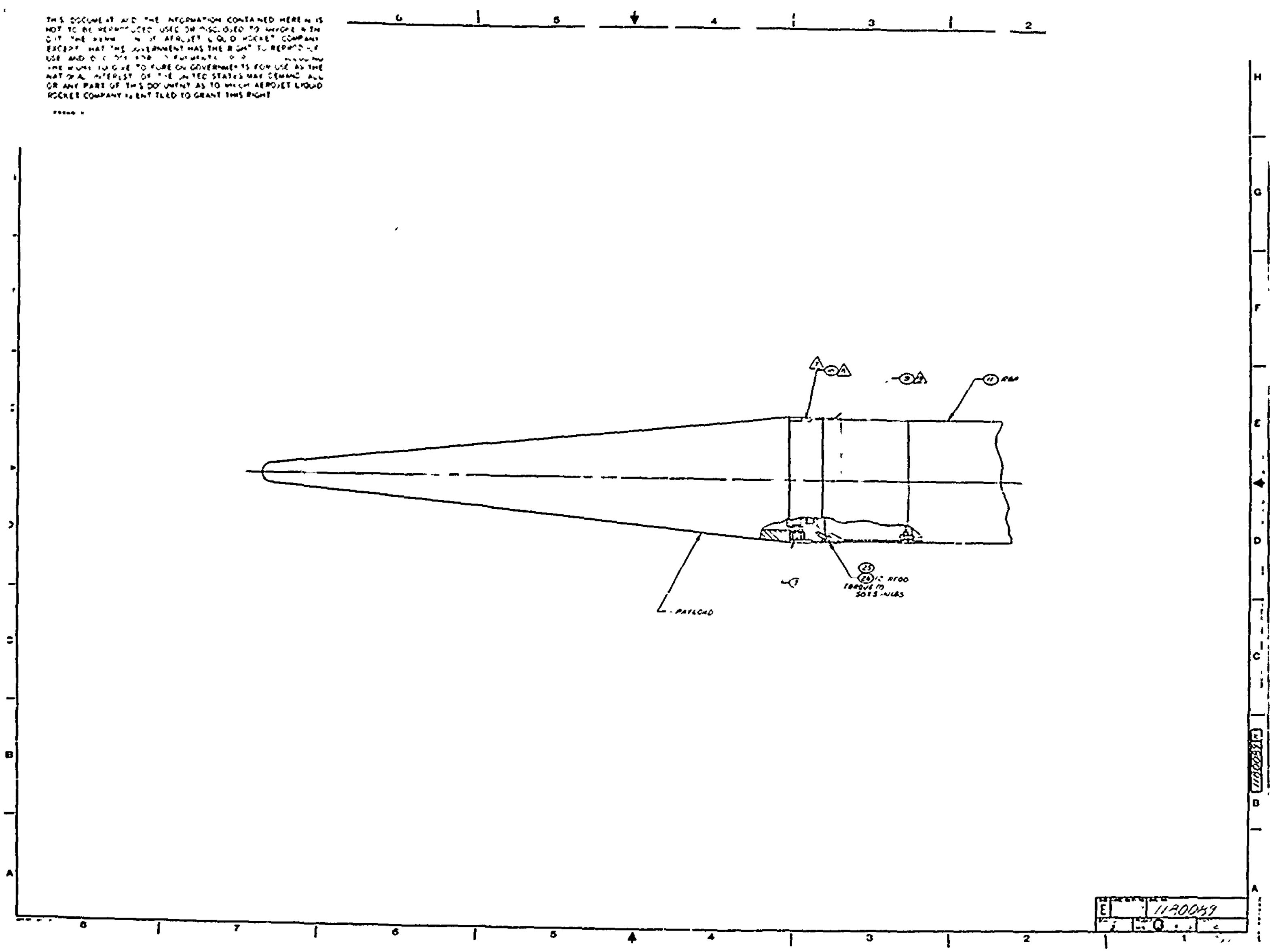


Figure 5. Main Assembly, FLAME - 1180089 (Sheet 2 of 4)

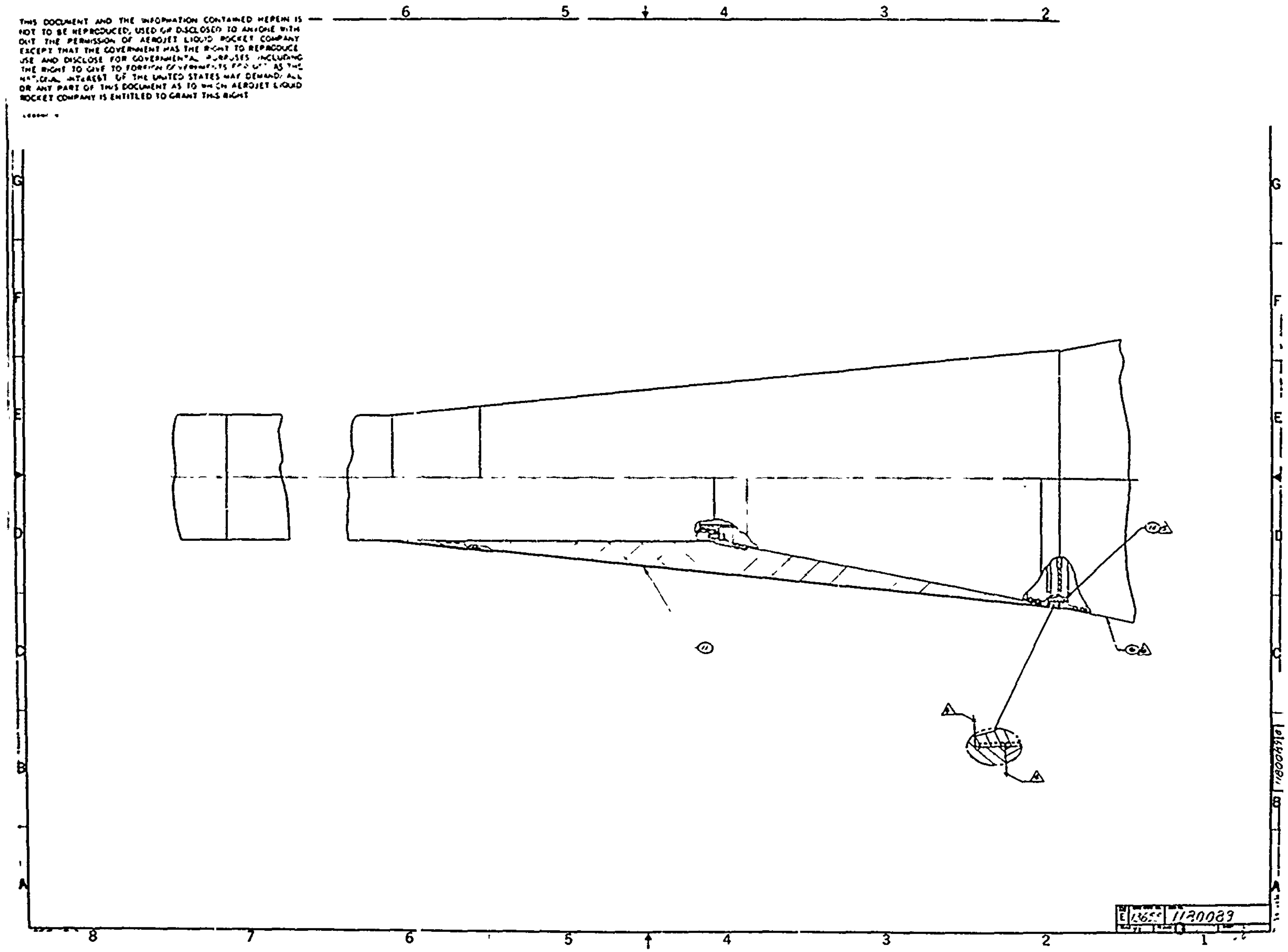


Figure 5. Main Assembly, FLAME - 1180089 (Sheet 3 of 4)

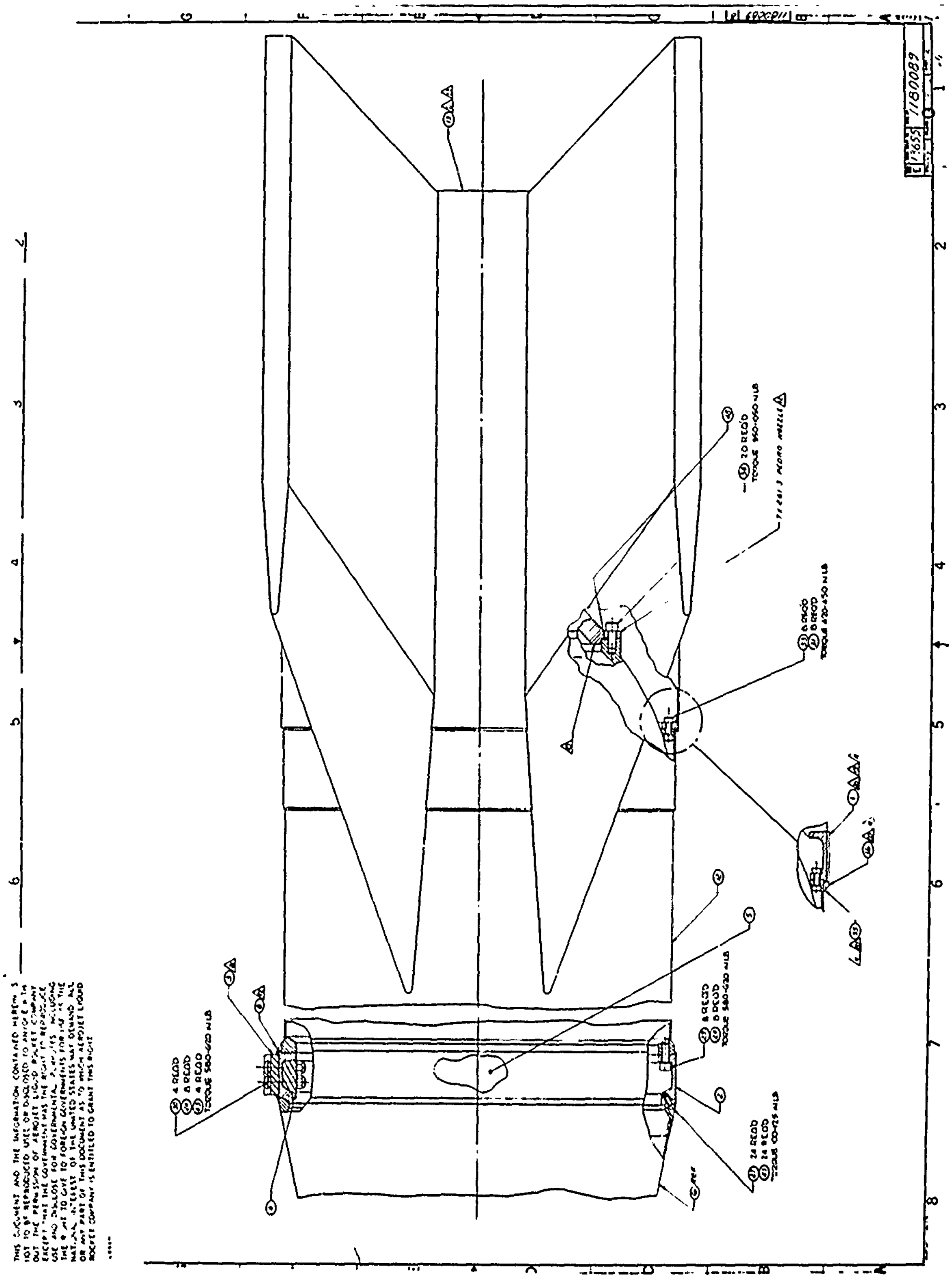


Figure 5. Main Assembly, FLAME - 1180089 (Sheet 4 of 4)

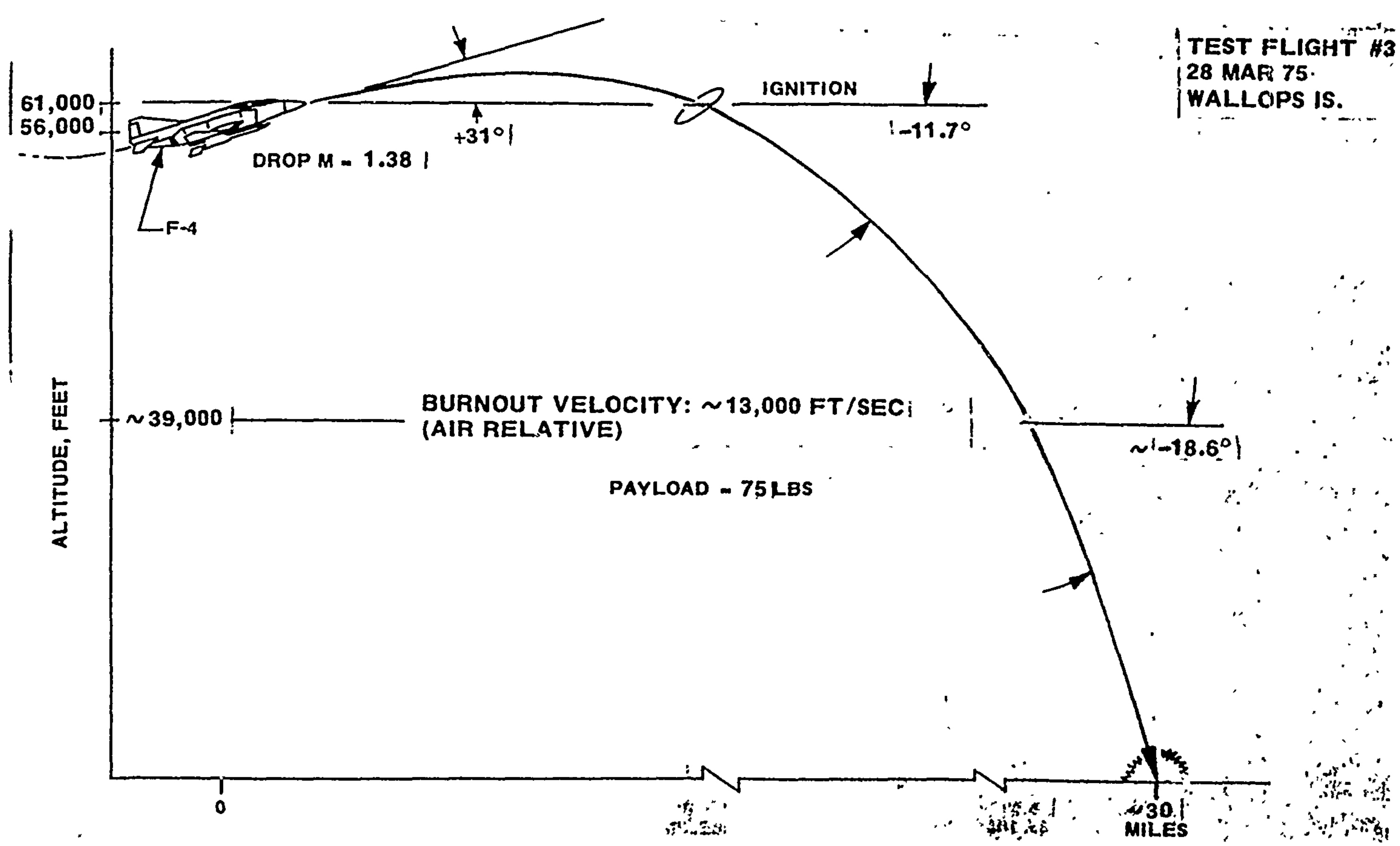


Figure 6. FLAME Flight Test Results - PEDRO/Recruit

C, Field Operations (cont.)

variety of aircraft and missile profiles may be flown to simulate conditions from reentry through ground impact.

Flights 07 and 08 took place at the TTR, with preflight operations at NWC-China Lake. During these operations, the total time required to install and final out the vehicle was reduced to approximately 90 minutes as compared with 4-1/2 hours during the early launches.

Flight 08 required payload external temperature control during flight line operations. This was accomplished with an electric blanket. The Flight 08 vehicle was installed on the aircraft on 23 January 1976 for an attempted launch. Unresolved software problems occurring during Flight 07 aborted the launch attempt, however, and the decision was made to store the vehicle on the aircraft over the weekend for a 26 January 1976 attempt. During this period, the motors were temperature conditioned under the aircraft with heating blankets. This further substantiates the program's fast reaction capability.

D. TEST RESULTS

The vehicles in Flights 07 and 08 performed as predicted, as can be seen in Table 3. Neither payload was successfully recovered, however, because of the following conclusions:

1. First-stage ignition on both flights occurred at an undesirably low angle (γ) due to erroneous radar/computer drop data.

2. The Flight 07 payload did not develop predicted drag at side panel separation due to cavity flow anomalies.

3. The Flight 07 payload impacted the ground before scheduled chute deployment due to low γ and low drag problems.

TABLE 3

FLAME PERFORMANCE SUMMARY

	FLIGHT 1 2/4/75	FLIGHT 2 2/27/75	FLIGHT 3 3/28/75	FLIGHT 4 4/18/75	FLIGHT 5 6/3/75	FLIGHT 6 6/4/75	FLIGHT 7 1/22/76	FLIGHT 8 1/26/76
AIRCRAFT DROP:								
Altitude	56,000 ft	55,100 ft	56,000 ft	56,100 ft	54,600 ft	55,200 ft	54,500 ft (est)	55,000 ft
Mach No.	1.36	1.3	1.38	1.25	1.2	1.3	1.1	1.3
Flight Path Angle (γ')	31.1°	30°	31°	32°	30°	29°	30.5°	31° (est)
1ST STAGE								
Ignition Altitude	62,750 ft (est)	59,914 ft	61,000 ft (est)	61,400 ft	59,960 ft	61,050 ft	59,350 ft	60,000 ft
Ignition γ'	-9.5°	-12.9°	-11.7°	-10.0°	-8.0°	-8.0°	-16.3° (est)	-13.7°
Burnout Velocity	7828 fps	7836 fps	7850 fps (est)	7500 fps	7800 fps	7700 fps	7750 fps	7850 fps
Burnout Roll Rate	1.3 cps	2.2 cps	2.2 cps	2.0 cps	N/A	N/A	1.46 cps	1.43 cps
2ND STAGE								
Burnout Altitude	45,000 ft	39,103 ft	39,000 ft (est)	-	N/A	-	34,000 ft	36,000 ft
Burnout Velocity	13,206 fps	13,157 fps	13,000 fps (est)	-	13,200 fps (est)	-	12,500 fps	12,750 fps
Burnout γ'	-15.5°	-18.6°	-18.6° (est)	-	N/A	-	-21.8°	-20.0°
VEHICLE RESULTS	Success	Success	Success	Failure	Success	Failure	Success	Success
COMMENTS	No Recovery	Chute Separated	Apparent Side Panel Problem	Apparent Exit Cone Problem (New Exit Cone)	Good Flight	Apparent Exit Cone Problem (New Exit Cone)	Pedro Fired at Low γ' Payload Flew into Ground	Apparent RV Failure in Free Flight

D, Test Results (cont.)

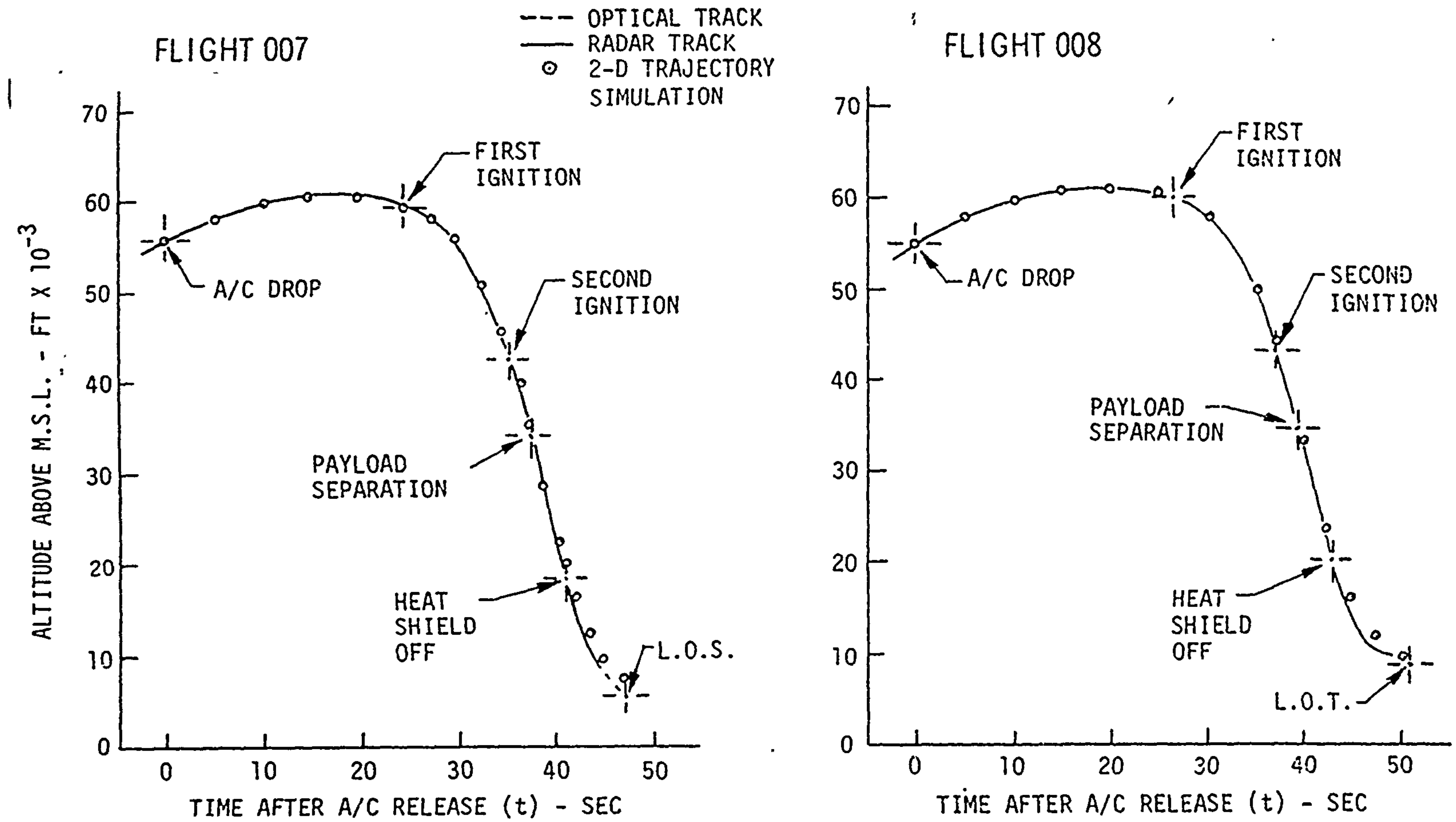
4. The Flight 08 payload broke up (probably near side panel deployment), possibly due to an anomaly associated with the nosetip gas generator and/or the tip boom attachment to the drogue body.

5. On Flight 08, radar tracks indicated the possibility of some erratic motions at or near the region where vehicle breakup is presumed to occur.

Figures 7 through 10 discuss the actual flight profiles of Flights 07 and 08. Included in the discussion is an analysis of tracking photo observations used in determining the flight anomalies previously discussed.

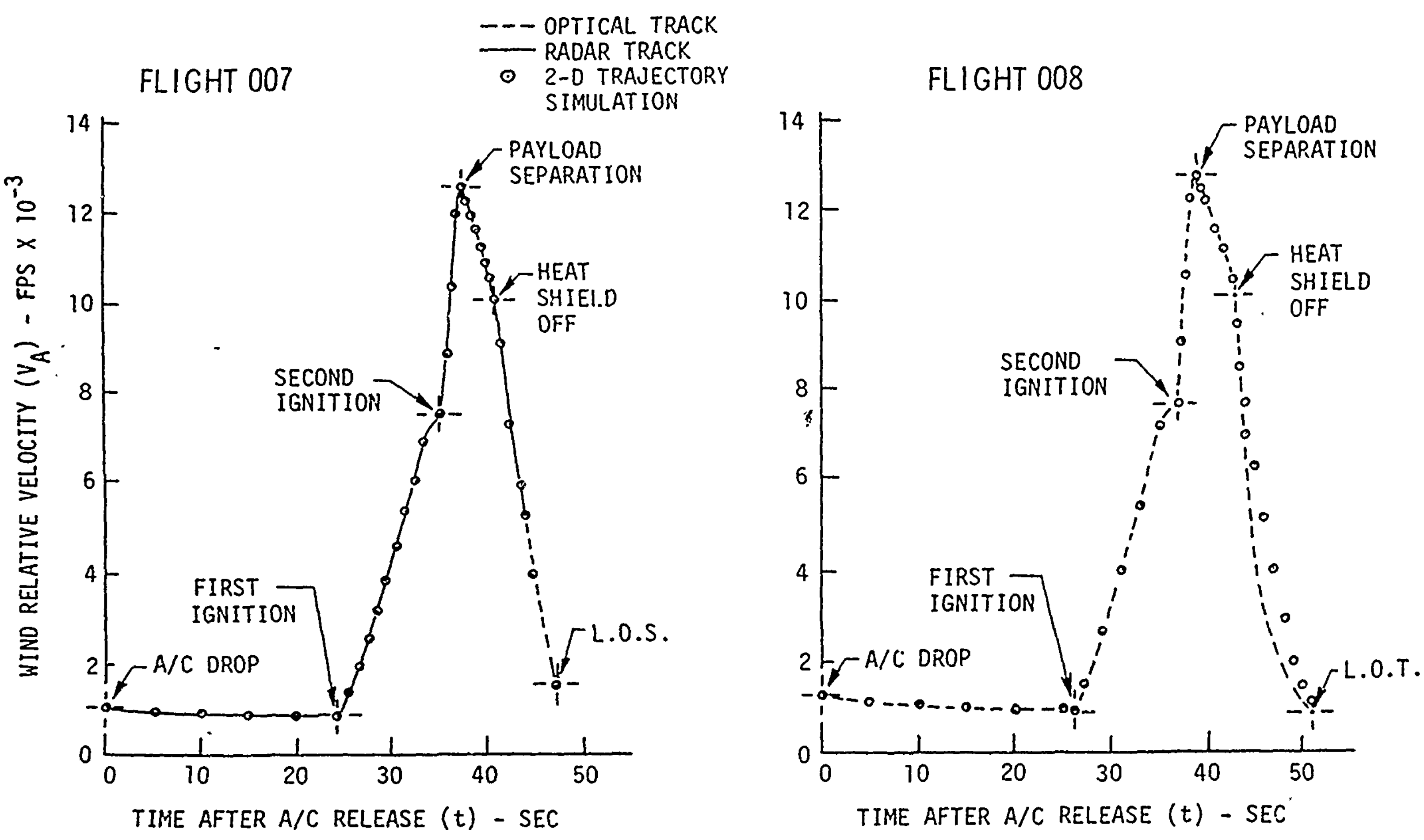
The following vehicle telemetry was monitored on Flight 07. Not included are those data associated with nozzle evaluation. It must be noted that vehicle telemetry is applicable only to coast and first-stage burn.

IRIG Channel		Function
Vehicle 07 Telemetry		
4	(Figure 11)	Pitch Acceleration ($\pm$ 5 g)
5	(Figure 12)	Yaw Acceleration ($\pm$ 5 g)
6	(Figure 13)	Axial Acceleration (0 to + 35 g)
17	(Figure 14)	First-Stage P_c (0 to + 1000 psi)
Payload 07 Telemetry		
10	(Figure 15)	Pitch Acceleration ($\pm$ 200 g)
12	(Figure 16)	Yaw Acceleration ($\pm$ 100 g)
15	(Figure 17)	Roll Rate Magnitude
E	(Figure 18)	Axial Acceleration (+ 200/- 400 g)



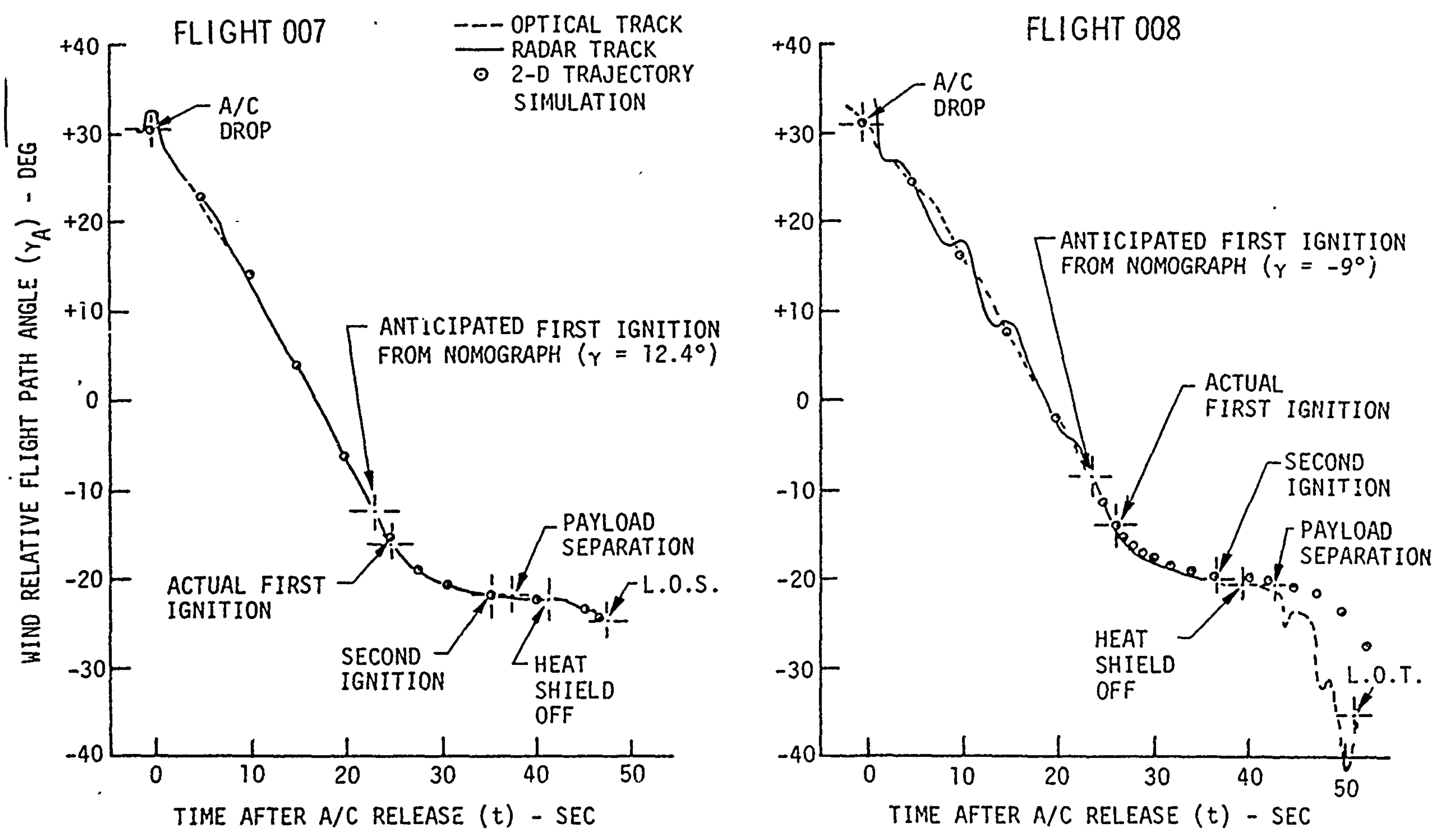
LOS - Loss of Signal
LOT - Loss of Track

Figure 7. FLAME Altitude vs Time



LOS - Loss of Signal
LOT - Loss of Track

Figure 8. FLAME Velocity vs Time



LOS - Loss of Signal
LOT - Loss of Track

Figure 9. FLAME Flight Path Angle vs Time

D, Test Results (cont.)

Because of radar track dropouts, extensive photo analysis was performed in an attempt to correlate failure mode with time and impact location.

Figure 10 provides the results of the analysis comparing Flights 07 and 08.

Frame 1 is selected to be the last frame before the fin panel deployment flash. Frames are numbered sequentially from Frame 1. Times are calculated assuming Frame 1 to be 0 sec. The actual frame rate of the tracking cameras (07: 113 pps; 08: 100 pps) were used. Real-time frame time could not be precisely established.

Flight 07 is presumed to be a "normal" deployment, thus limited comments are given on individual frames in above Flight 08 comments in Figure 10.

Upon examination, the following observations can be made:

1. Flight 07 has no visible wake other than pyrotechnic event smoke. Flight 08 developes distinct white wake after first event which remains through sequence.

2. Three distinct flashes (pyro events?) are visible on Flight 08. Burning in wake occurs on all three.

3. Two "long" pieces seen separating from 08.

4. Side panels visible on 07 at Frame 5 or 6; on 08 at Frame 11.

5. Visual intensity of tip (08) increases after first and again after third pyro events. Flight 07 tip does not change in intensity.

Frame No.	Time: Flight 007	Time: Flight 008	Comments (008)
1	0	0	Reference frame prior to 1st pyrotechnic event.
2	0.009	0.010	First flash visible.
3	0.018	0.020	-
4	0.027	0.030	White wake established. Piece visible (1 frame only). Burning in wake.
5	0.035	0.040	(007 peices visible.) No pieces visible.
6	0.044	0.050	(007 side panel visible, no wake.) No pieces visible on 008.
7	0.053	0.060	(007 side panels well separated. No further events.) Start of 2nd pyrotechnic event on 008 (probably panel deployment).
8	0.062	0.070	Flash brightens, long piece visible above wake.
9	0.071	0.080	Flash diminishes, wake burning, long piece visible.
10	0.080	0.090	2nd piece visible (bright 1 frame only), long piece moving rearward.
11	0.089	0.100	1 side panel visible close to body for first time. Long piece visible.
12	0.097	0.110	Start of 3rd pyro event. Very bright. Side panel barely visible, long piece visible top of frame.
13	0.106	0.120	Pyro intensity brightens, side panel visible.

Frame No.	Time: Flight 007	Time: Flight 008	Comments (008)
14	0.115	0.130	Pyro intensity brightens, side panel visible.
15	0.124	0.140	Pyro intensity brightens, side panel visible.
16	0.133	0.150	Second side panel visible above wake, wake burning.
17	0.142	0.160	Flash dims, wake burning, 3rd piece visible below wake.
18	0.150	0.190	4 pieces visible, long piece from 17 moves back.
19	0.159	0.180	Long piece obscured by wake?
20	0.168	0.190	Long piece obscured by wake? Top side panel intensity diminishes (rolling?).
21	0.177	0.200	Long piece visible above wake, top of frame, small piece near top side panel.
22	0.186	0.210	Small piece passes side panel. White wake constant and remains so through sequence.
23	0.195	0.220	Last frame with pieces other than side panels visible.
24	0.204	0.230	No further events other than variable intensity of side panels.
25	0.212	0.240	-

Figure 10. FLAME Flights 07 & 08 Still Photo Correlation

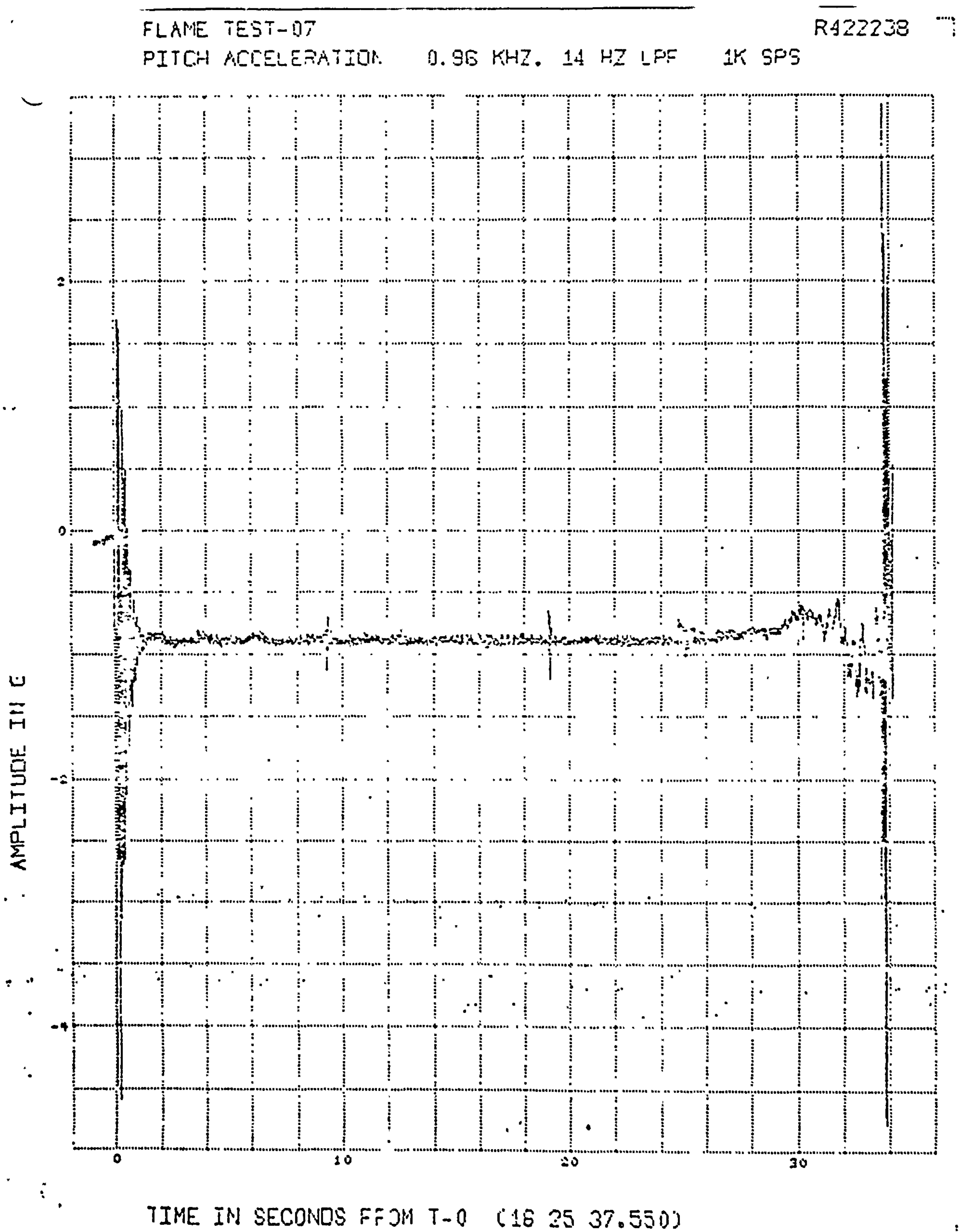


Figure 11. Channel 4 Pitch Acceleration

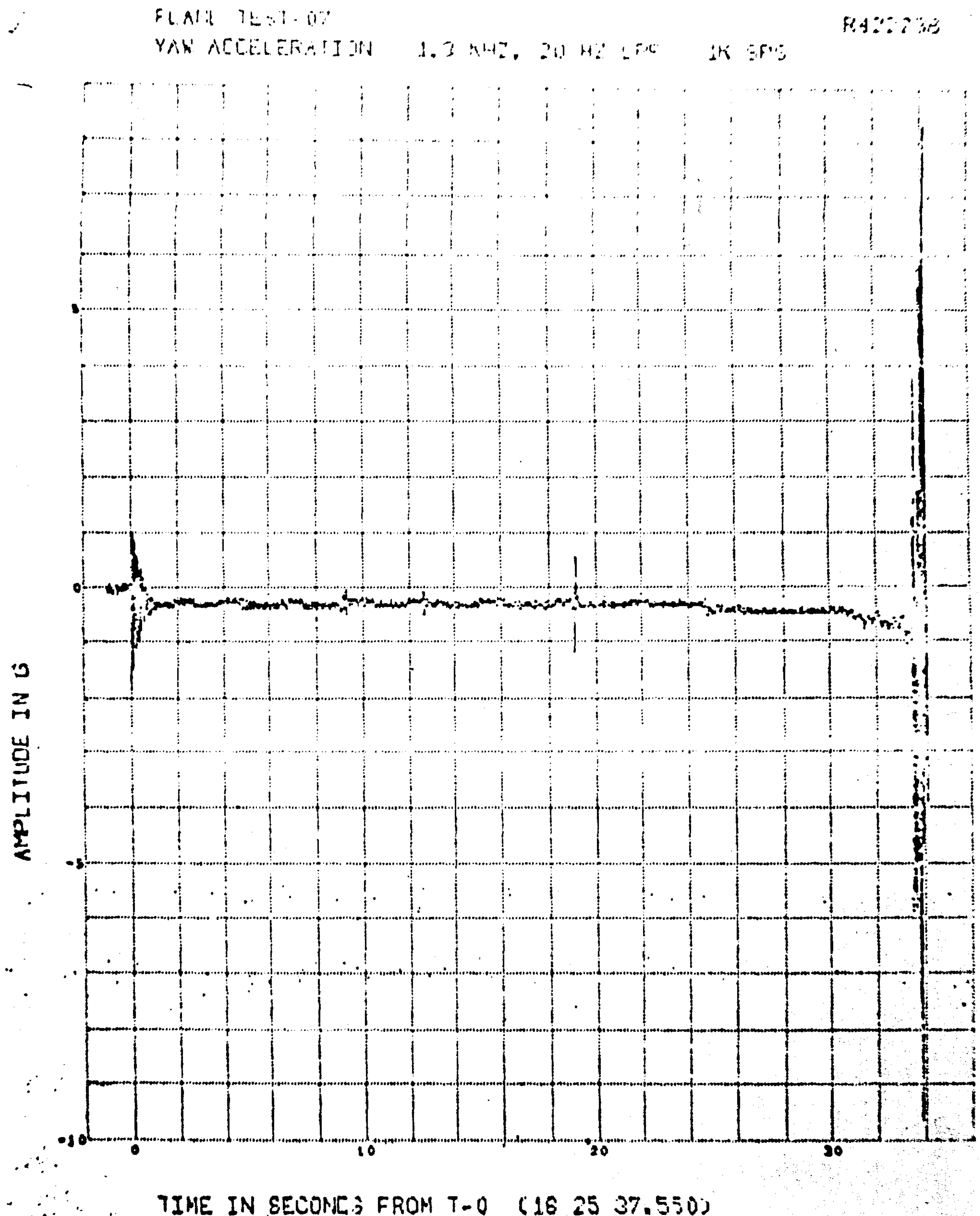


Figure 12. Channel 5 Yaw Acceleration

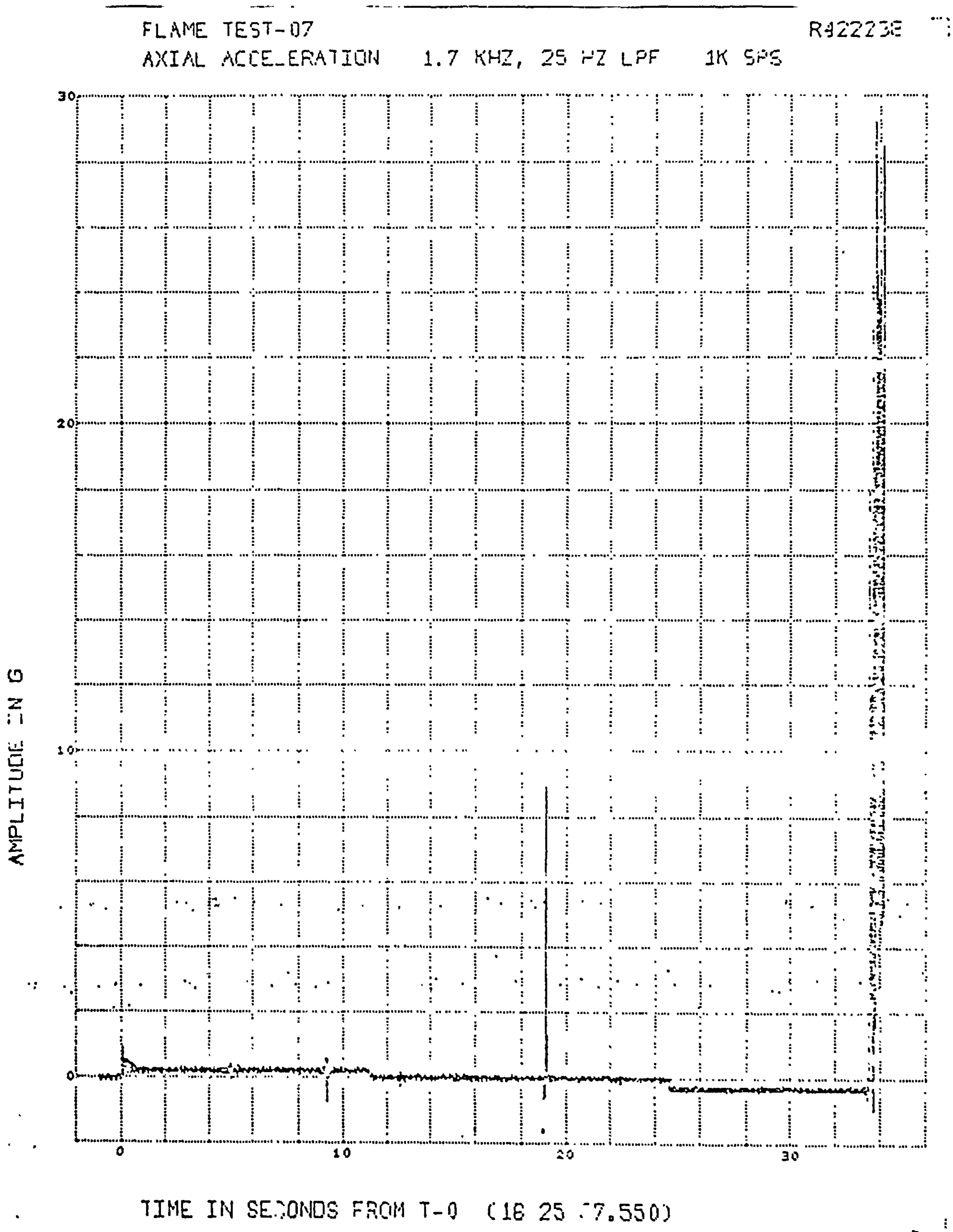


Figure 13. Channel 6 Axial Acceleration

BEST AVAILABLE COPY

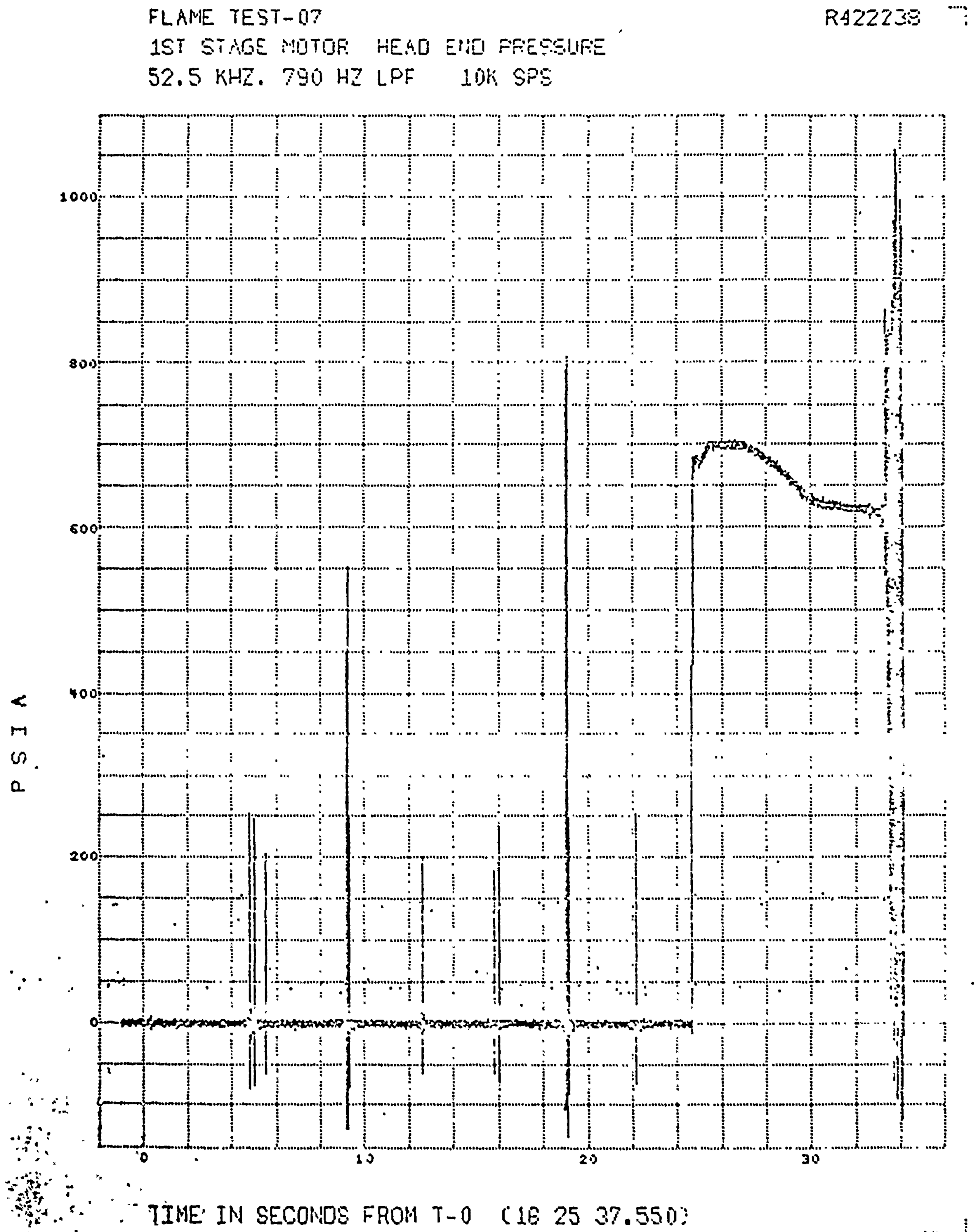


Figure 14. Channel 17 1st Stage Motor Head End Pressure

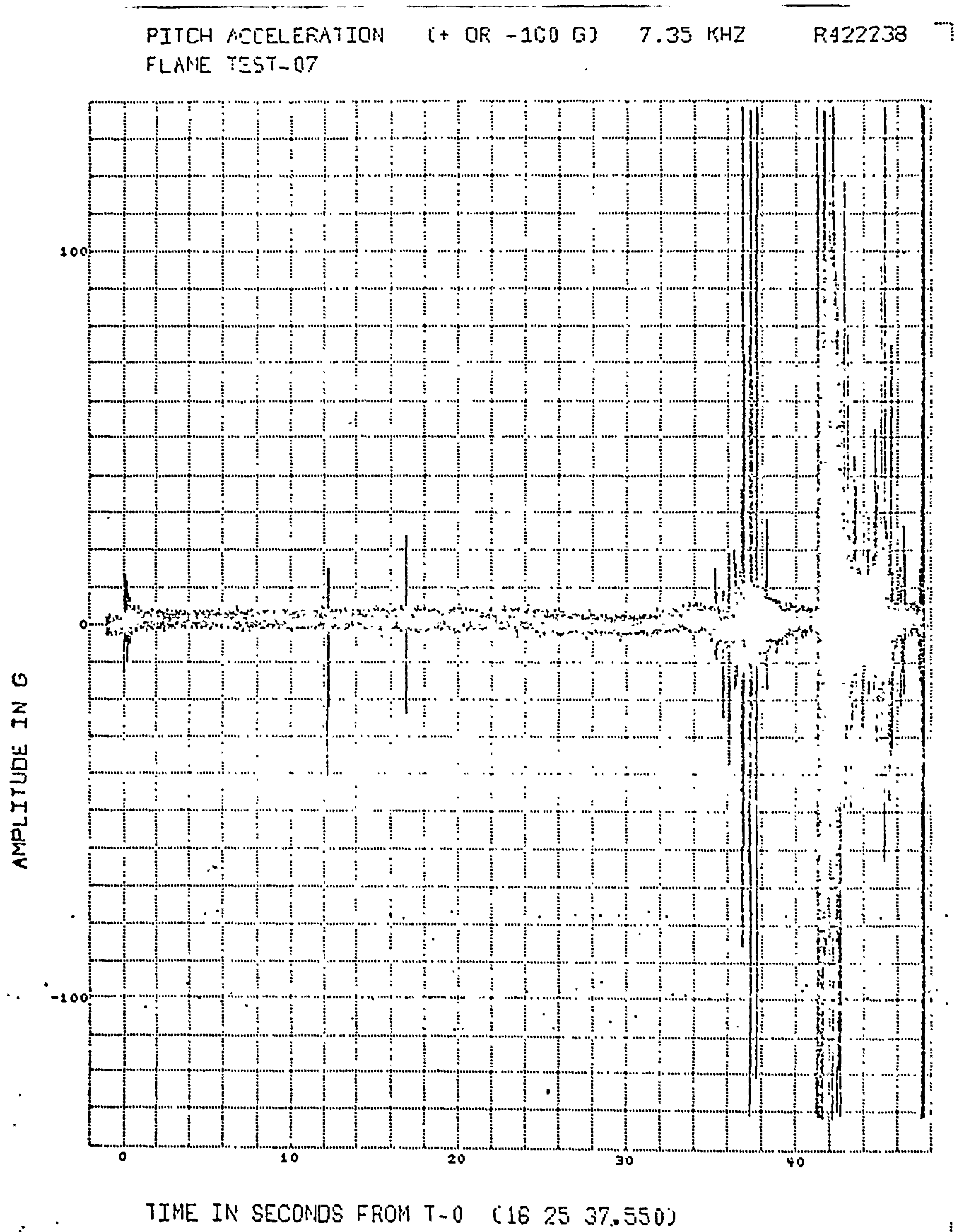


Figure 15. Payload Pitch Acceleration

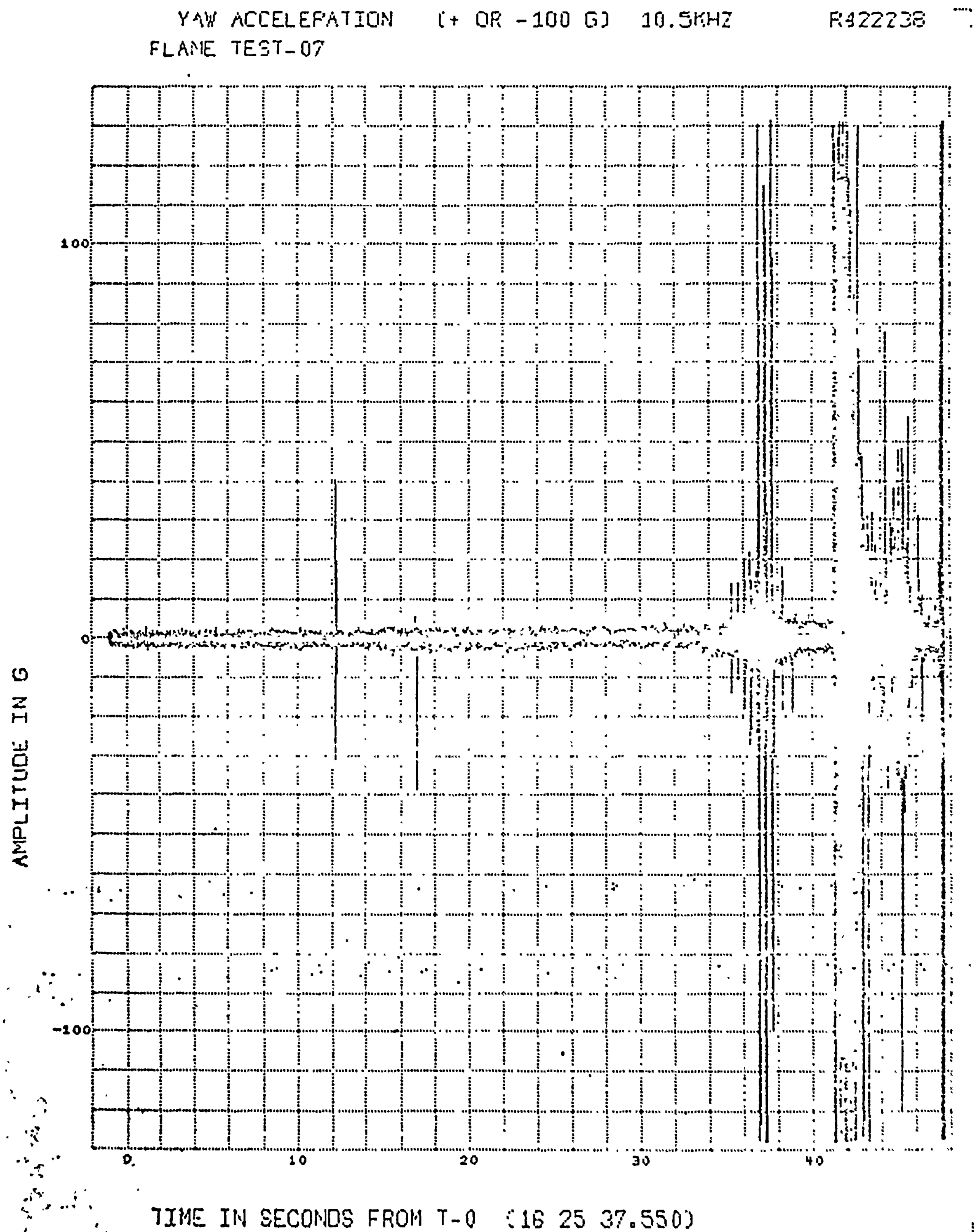
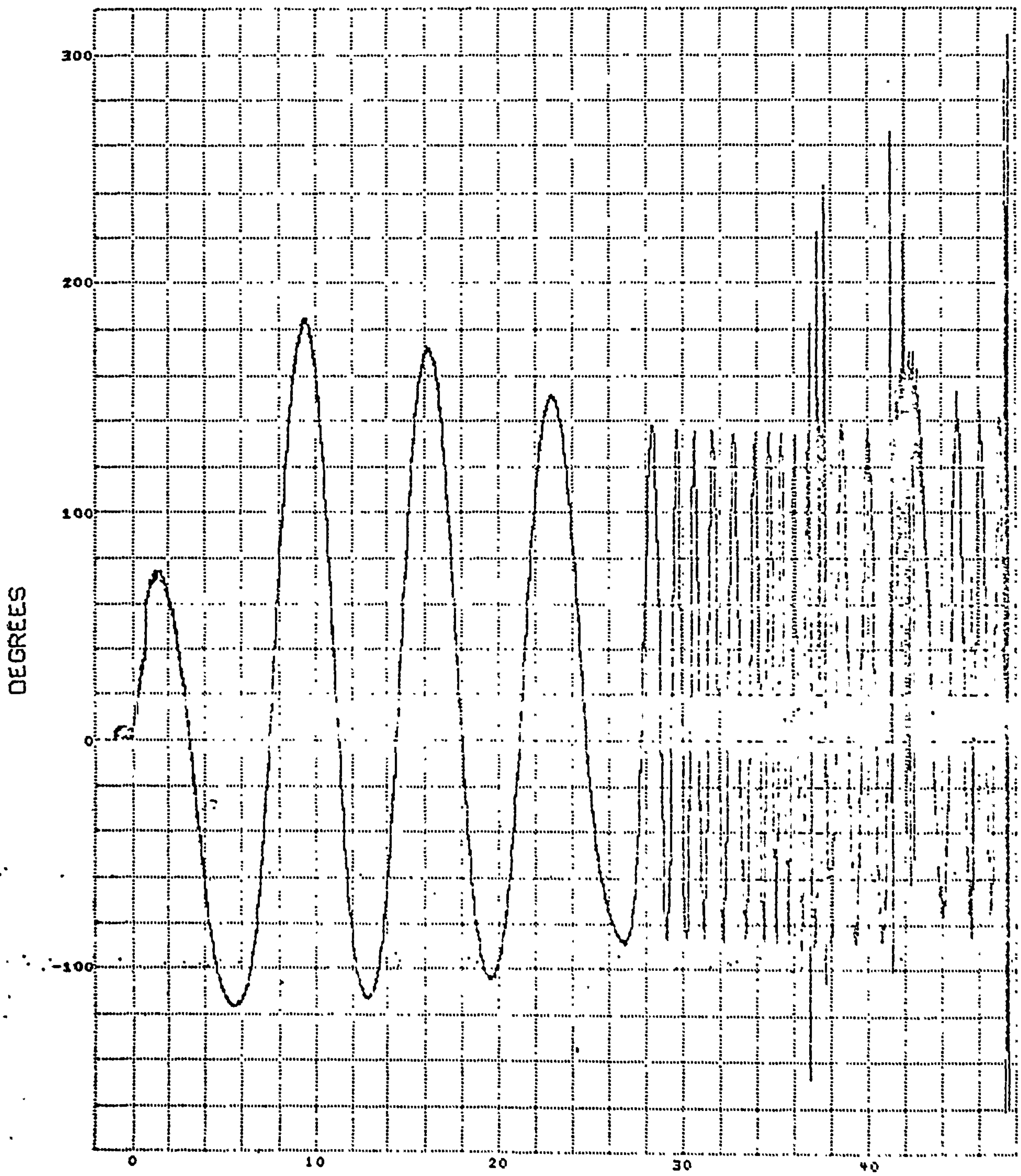


Figure 16. Payload Yaw Acceleration

ROLL RATE MAGNETOMETER (0 TO 360 DEGREES) 30.0KHZ R422238
FLAME TEST-07



TIME IN SECONDS FROM T-0 (16 25 37.550)

Figure 17. Payload Roll Rate Magnetometer

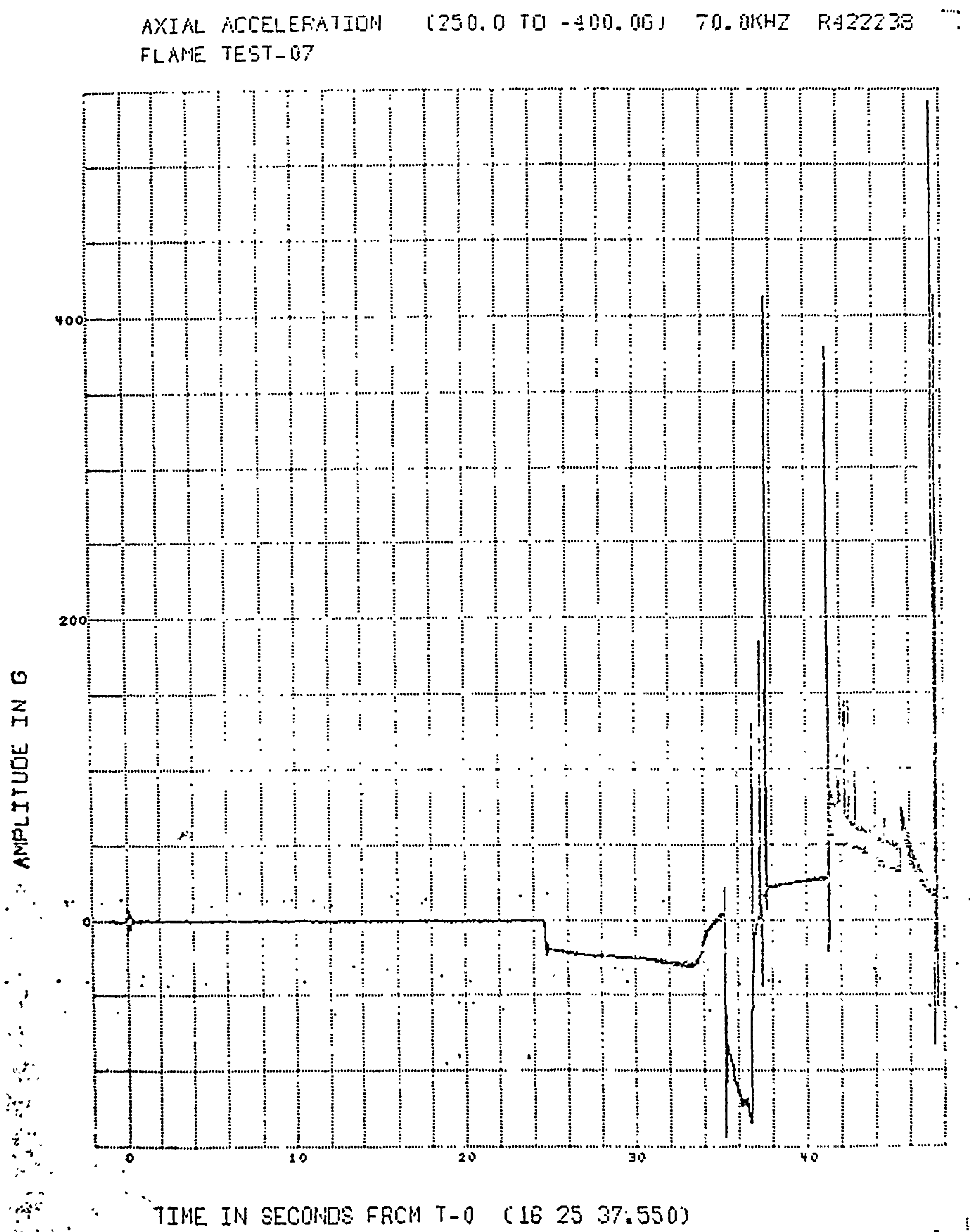


Figure 18. Payload Axial Acceleration

D, Test Results (cont.)

Vehicle 08 Telemetry

Vehicle 08 was not instrumented because of a lack of space available in the payload. The areas normally housing the telemetry system were required to house the nosetip support equipment.

APPENDIX A

2-D MASS TRAJECTORY
FLAME VEHICLE 08 FLIGHT SIMULATION

NOTE: Stage 1 - Coast Period
2 - First-Stage Burn
3 - Second-Stage Burn
4 - 7 - Payload After Vehicle/Payload Separation

APPENDIX A

2-D MASS TRAJECTORY
FLAME VEHICLE 08 FLIGHT SIMULATION

NOTE: Stage 1 - Coast Period
2 - First-Stage Burn
3 - Second-Stage Burn
4 - 7 - Payload After Vehicle/Payload Separation

ASE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

PL = 82.5 Lbs

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
1	.000	1240.0	55275.0	-.84	.00	1297.756	.0	6.762
	1.281	.0	58.90	3967.30	.00	.883	217.5	.000
	.000	.0	.00	.00	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	1.000	1213.6	55896.9	-.80	.00	1205.436	.0	6.762
	1.254	1054.5	60.19	3967.30	.00	.882	202.2	.000
	.000	1250.8	.00	-1250.80	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	2.000	1188.6	56482.0	-.76	.00	1123.519	.0	6.762
	1.228	2100.5	61.52	3967.30	.00	.881	188.6	.000
	.000	2414.5	.00	-2414.47	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	3.000	1164.9	57030.8	-.72	.00	1049.988	.0	6.762
	1.203	3138.5	62.89	3967.30	.00	.880	176.4	.000
	.000	3500.6	.00	-3500.56	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	4.000	1142.4	57543.7	-.68	.00	978.220	.0	6.762
	1.180	4168.9	64.31	3967.30	.00	.873	165.6	.000
	.000	4514.5	.00	-4514.47	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	5.000	1121.3	58021.3	-.64	.00	913.197	.0	6.762
	1.158	5192.0	65.78	3967.30	.00	.866	155.9	.000
	.000	5459.5	.00	-5459.54	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

CASE 8149 FLAME FLT (8 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
1	6.000	1101.3	58463.9	-.60	.00	856.073	.0	6.762
	1.138	6208.4	67.29	3967.30	.00	.859	147.3	.000
	.000	6343.6	.00	-6343.64	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	7.000	1082.7	58871.9	-.56	.00	805.161	.0	6.762
	1.118	7218.4	68.84	3967.30	.00	.853	139.6	.000
	.000	7173.8	.00	-7173.77	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	8.000	1065.2	59245.5	-.52	.00	760.300	.0	6.762
	1.100	8222.2	70.44	3967.30	.00	.847	132.7	.000
	.000	7956.0	.00	-7955.99	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	9.000	1049.0	59585.2	-.48	.00	697.767	.0	6.762
	1.084	9220.3	72.08	3967.30	.00	.815	126.7	.000
	.000	8684.5	.00	-8684.46	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	10.000	1034.2	59891.1	-.44	.00	643.468	.0	6.762
	1.068	10212.9	73.76	3967.30	.00	.784	121.3	.000
	.000	9354.4	.00	-9354.41	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	11.000	1020.7	60163.7	-.40	.00	596.997	.0	6.762
	1.054	11200.5	75.48	3967.30	.00	.757	116.6	.000
	.000	9974.0	.00	-9974.01	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

SE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
1	12.000	1008.4	60403.1	-.36	.00	557.285	.0	6.762
	1.042	12183.4	77.23	3967.30	.00	.732	112.6	.000
	.000	10550.6	.00	-10550.64	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	13.000	997.5	60609.5	-.32	.00	523.430	.0	6.762
	1.030	13161.9	79.02	3967.30	.00	.710	109.0	.000
	.000	11090.5	.00	-11090.54	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	14.000	987.7	60783.2	-.28	.00	494.805	.0	6.762
	1.020	14136.2	80.83	3967.30	.00	.690	106.0	.000
	.000	11599.2	.00	-11599.25	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	15.000	979.2	60924.3	-.25	.00	470.888	.0	6.762
	1.012	15106.6	82.67	3967.30	.00	.673	103.5	.000
	.000	12081.7	.00	-12081.73	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	16.000	971.9	61033.0	-.21	.00	451.280	.0	6.762
	1.004	16073.2	84.54	3967.30	.00	.658	101.4	.000
	.000	12542.5	.00	-12542.46	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	17.000	965.8	61109.4	-.17	.00	438.439	.0	6.762
	.998	17036.1	86.42	3967.30	.00	.650	99.8	.000
	.000	12986.2	.00	-12986.17	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

CASE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
1	18.000	960.8	61153.6	-.14	.00	432.411	.0	6.762
	.993	17995.4	88.32	3967.30	.00	.649	98.6	.000
	.000	13421.4	.00	-13421.44	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	19.000	956.9	61165.8	-.10	.00	428.201	.0	6.762
	.988	18951.3	90.23	3967.30	.00	.648	97.7	.000
	.000	13851.6	.00	-13851.60	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	20.000	954.1	61146.1	-.07	.00	425.761	.0	6.762
	.986	19903.7	92.14	3967.30	.00	.647	97.2	.000
	.000	14278.4	.00	-14278.43	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	21.000	952.4	61094.5	-.04	.00	425.052	.0	6.762
	.984	20852.7	94.06	3967.30	.00	.647	97.1	.000
	.000	14703.7	.00	-14703.70	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	22.000	951.8	61011.3	-.00	.00	426.048	.0	6.762
	.983	21798.2	95.97	3967.30	.00	.647	97.4	.000
	.000	15129.1	.00	-15129.11	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	23.000	952.2	60896.5	.03	.00	428.835	.0	6.762
	.984	22740.4	97.88	3967.30	.00	.647	98.0	.000
	.000	15556.4	.00	-15556.40	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

SE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
1	24.000	953.6	60750.2	.06	.00	433.348	.0	6.762
	.985	23679.1	99.78	3967.30	.00	.647	99.0	.000
	.000	15987.4	.00	-15987.35	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	25.000	956.0	60572.5	.09	.00	439.583	.0	6.762
	.988	24614.3	101.67	3967.30	.00	.648	100.3	.000
	.000	16423.7	.00	-16423.67	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	26.000	959.4	60363.6	.12	.00	447.553	.0	6.762
	.991	25546.1	103.53	3967.30	.00	.648	102.1	.000
	.000	16867.1	.00	-16867.10	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
1	26.200	960.2	60318.1	.13	.00	449.357	.0	6.762
	.992	25732.1	103.90	3967.30	.00	.649	102.5	.000
	.000	16956.6	.00	-16956.79	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
2	26.200	960.2	60318.1	16.32	64129.40	328.393	263.6	6.762
	.992	25732.1	103.90	3967.30	.00	.474	102.5	4.310
	1.000	.0	.00	.00	64770.70	266.248	.0	.000
	.000	.000	.000	.000	.000	243.272	.000	.000
2	27.200	1500.2	60005.7	17.28	64361.86	1003.547	263.6	6.762
	1.550	26915.8	105.37	3723.57	64891.67	.585	253.8	4.310
	1.000	686.9	64246.04	63559.12	65012.65	266.248	.0	.000
	.000	.000	.000	.000	.000	244.181	.000	.000

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CASE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
2	28.200 2.143 1.000 .000	2075.1 28626.9 1820.6 .000	59516.4 106.36 128721.58 .000	18.48 3478.94 126900.94 .000	64588.23 130025.28 65254.60 .000	1275.056 .379 266.248 245.090	263.5 497.3 .0 .000	6.762 4.310 .000 .000
2	29.200 2.774 1.000 .000	2685.6 30897.1 3314.9 .000	58830.9 107.09 192936.68 .000	19.49 3235.21 189621.76 .000	63840.72 194917.16 64529.20 .000	1731.736 .298 266.248 242.365	263.4 860.6 .0 .000	6.762 4.310 .000 .000
2	30.200 3.440 1.000 .000	3330.4 33756.6 5315.4 .000	57932.1 107.67 256400.28 .000	20.60 2994.21 251084.89 .000	63085.17 259083.64 63803.80 .000	2297.355 .246 266.248 239.641	263.2 1381.3 .0 .000	6.762 4.310 .000 .000
2	31.200 4.138 1.000 .000	4005.7 37235.1 7954.6 .000	56804.2 108.14 318499.62 .000	21.37 2758.20 310545.02 .000	61111.93 321920.73 61870.46 .000	3013.999 .211 266.248 232.379	263.0 2109.2 .0 .000	6.762 4.310 .000 .000
2	32.200 4.861 1.000 .000	4705.6 41356.3 11417.7 .000	55434.1 108.53 378620.21 .000	22.14 2529.45 367202.48 .000	59127.16 382824.48 59937.11 .000	3924.641 .187 266.248 225.118	262.7 3108.0 .0 .000	6.762 4.310 .000 .000
2	33.200 5.626 1.000 .000	5446.8 46147.3 15885.3 .000	53808.1 108.86 437957.93 .000	23.97 2303.43 422072.66 .000	59545.65 443003.49 60421.00 .000	5062.335 .166 266.248 226.935	262.4 4500.5 .0 .000	6.762 4.310 .000 .000

BEST AVAILABLE COPY

E 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

TAGE	TIME,SEC	VEL.,FT/SEC	ALTITUDE,FT	ACC.,G	THRUST,LB	DRAG,LB	ISP,SEC	S,SQFT
	MACH NO.	RANGE,FT	GAMMA,DEG	WEIGHT,LB	IT(VAC),LB-SEC	CD	Q,LB/SQFT	AE,SQFT
	TYPE	IT(DRG)	IT(THRST)	IT(T-D)	THRUST-VAC	ISP(VAC)	PC,PSF	AT,SQFT
	PC/PO	RATIO SP HT	PROP EFF	EXP RATIO	THRST COEFF	WDOT	CD-BASE	BASE AREA
2	34.200	6250.9	51905.1	26.02	59945.33	6611.102	262.1	6.762
	6.457	51658.2	109.14	2075.59	503665.95	.151	6491.6	4.310
	1.000	21656.2	497705.01	476048.85	60904.00	266.248	.0	.000
	.000	.000	.000	.000	.000	228.749	.000	.000
2	35.200	7119.2	49700.1	26.93	57904.80	8780.605	261.4	6.762
	7.354	57951.1	109.38	1846.84	564569.90	.139	9358.1	4.310
	1.000	29301.8	557599.09	528297.26	58970.24	266.248	.0	.000
	.000	.000	.000	.000	.000	221.486	.000	.000
2	36.200	7630.1	47217.5	5.76	20068.65	10850.152	251.2	6.762
	7.888	64948.7	109.60	1700.33	603577.68	.132	12123.6	4.310
	1.000	39192.1	595476.46	556284.39	21268.40	266.248	.0	.000
	.000	.000	.000	.000	.000	79.882	.000	.000
2	36.900	7695.7	45408.7	-.43	10679.20	11950.310	237.2	6.762
	7.949	69998.2	109.74	1656.79	615168.77	.132	13427.8	4.310
	1.000	47180.4	606190.41	559010.02	11987.52	266.248	.0	.000
	.000	.000	.000	.000	.000	45.024	.000	.000
3	36.900	7695.7	45408.7	78.74	42597.22	1319.740	231.1	4.508
	7.949	69998.2	109.74	526.50	.00	.022	13427.8	1.485
	1.000	.0	.00	.00	43048.00	233.498	.0	.000
	.000	.000	.000	.000	.000	184.361	.000	.000
3	37.400	9030.3	43995.1	87.52	39896.14	1780.753	230.7	4.508
	9.328	73918.8	109.83	437.18	20856.57	.020	19777.9	1.485
	1.000	769.8	20623.61	19853.81	40378.34	233.498	.0	.000
	.000	.000	.000	.000	.000	172.928	.000	.000

ASE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC	VEL.,FT/SEC	ALTITUDE,FT	ACC.,G	THRUST,LB	DRAG,LB	ISP,SEC	S,SQFT
	MACH NO.	RANGE,FT	GAMMA,DEG	WEIGHT,LB	IT(VAC),LB-SEC	CD	Q,LB/SQFT	AE,SQFT
	TYPE	IT(DRG)	IT(THRST)	IT(T-D)	THRUST-VAC	ISP(VAC)	PC,PSF	AT,SQFT
	PC/PO	RATIO SP HT	PROP EFF	EXP RATIO	THRST COEFF	WDOT	CD-BASE	BASE AREA
3	37.900	10524.3	42335.8	98.76	37186.48	2388.360	230.3	4.508
	10.871	78499.6	109.91	353.57	40378.31	.018	29091.6	1.485
	1.000	1808.8	39894.64	38085.84	37708.67	233.498	.0	.000
	.000	.000	.000	.000	.000	161.495	.000	.000
3	38.400	12229.0	40399.3	113.97	34466.08	3141.115	229.7	4.508
	12.632	83827.0	109.97	275.69	58565.23	.016	43095.3	1.485
	1.000	3180.7	57808.31	54627.65	35039.00	233.498	.0	.000
	.000	.000	.000	.000	.000	150.061	.000	.000
3	38.900	12767.5	38237.3	3.10	4369.63	3684.109	203.9	4.508
	13.188	89757.1	110.02	248.25	64972.35	.016	52094.5	1.485
	1.000	4907.1	63913.73	59006.62	5005.00	233.498	.0	.000
	.000	.000	.000	.000	.000	21.435	.000	.000
3	39.000	12762.9	37600.0	-5.97	2203.71	3759.962	180.4	4.508
	13.184	90954.5	110.03	246.56	65365.23	.016	53157.5	1.485
	1.000	5279.4	64242.40	58963.05	2852.52	233.498	.0	.000
	.000	.000	.000	.000	.000	12.216	.000	.000
4	39.000	12762.9	37800.0	-17.13	.00	1441.540	.0	.440
	13.184	90954.5	110.03	82.50	.00	.062	53157.5	.000
	.000	.0	.00	.00	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
4	39.500	12477.6	35635.6	-18.29	.00	1537.176	.0	.440
	12.859	96872.2	110.08	82.50	.00	.062	56092.9	.000
	.000	745.7	.00	-745.66	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

20-POINT MASS TRAJECTORY PROGRAM ALPHA=0,LIFT=0 JOB 0022

E 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
4	40.000	12176.3	33516.1	-19.16	.00	1609.311	.0	.440
	12.429	102650.9	110.14	82.50	.00	.063	57926.3	.000
	.000	1532.5	.00	-1532.54	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
4	40.500	11861.7	31444.2	-19.94	.00	1673.281	.0	.440
	11.998	108283.7	110.19	82.50	.00	.064	59417.0	.000
	.000	2353.5	.00	-2353.49	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
4	41.000	11535.5	29422.0	-20.60	.00	1728.043	.0	.440
	11.566	113764.8	110.25	82.50	.00	.065	60544.7	.000
	.000	3204.2	.00	-3204.16	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
4	41.500	11199.6	27451.5	-21.14	.00	1772.765	.0	.440
	11.136	119089.2	110.31	82.50	.00	.066	61297.8	.000
	.000	4079.7	.00	-4079.74	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
4	42.000	10856.0	25534.3	-21.55	.00	1806.804	.0	.440
	-10.708	124252.7	110.38	82.50	.00	.067	61671.5	.000
	.000	4975.0	.00	-4975.01	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
4	42.500	10506.9	23671.5	-21.83	.00	1829.875	.0	.440
	10.284	129252.4	110.45	82.50	.00	.067	61674.1	.000
	.000	5884.6	.00	-5884.59	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

ASE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
4	42.550 10.242 .000 .000	10471.8 129743.3 5976.1 .000	23488.3 110.45 .00 .000	-21.85 82.50 -5976.12 .000	.00 .00 .00 .000	1831.617 .068 .000 .000	.0 61655.9 .0 .000	.440 .000 .000 .000
5	42.550 10.242 .000 .000	10471.8 129743.3 .0 .000	23488.3 110.45 .00 .000	-69.91 46.34 .00 .000	.00 .00 .00 .000	3256.201 .114 .000 .000	.0 61655.9 .0 .000	.463 .000 .000 .000
5	43.050 9.154 .000 .000	9426.1 134392.0 1514.3 .000	21749.4 110.53 .00 .000	-60.35 46.34 -1514.34 .000	.00 .00 .00 .000	2812.775 .115 .000 .000	.0 53048.9 .0 .000	.463 .000 .000 .000
5	43.550 8.225 .000 .000	8522.7 138583.9 2823.6 .000	20175.0 110.61 .00 .000	-52.18 46.34 -2823.65 .000	.00 .00 .00 .000	2434.502 .115 .000 .000	.0 45759.9 .0 .000	.463 .000 .000 .000
5	44.050 7.422 .000 .000	7734.3 142379.7 3967.4 .000	18742.6 110.71 .00 .000	-46.23 46.34 -3967.44 .000	.00 .00 .00 .000	2158.829 .118 .000 .000	.0 39551.9 .0 .000	.463 .000 .000 .000
5	44.550 6.714 .000 .000	7032.5 145825.5 4986.5 .000	17435.3 110.81 .00 .000	-41.09 46.34 -4986.47 .000	.00 .00 .00 .000	1920.441 .121 .000 .000	.0 34158.0 .0 .000	.463 .000 .000 .000

2D-POINT MASS TRAJECTORY PROGRAM ALPHA=0,LIFT=0

E 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

TAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
5	45.050	6410.1	16239.1	-36.38	.00	1702.340	.0	.463
	6.091	148960.2	110.93	46.34	.00	.125	29522.0	.000
	.000	5891.2	.00	-5891.23	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	45.550	5819.8	15143.0	-37.66	.00	1761.965	.0	.463
	5.507	151813.8	111.07	46.34	.00	.151	25223.1	.000
	.000	6750.0	.00	-6750.00	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	46.050	5210.8	14148.6	-37.64	.00	1760.934	.0	.463
	4.912	154384.0	111.22	46.34	.00	.182	20884.7	.000
	.000	7635.5	.00	-7635.52	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	46.550	4619.5	13256.5	-35.59	.00	1666.175	.0	.463
	4.340	156671.0	111.38	46.34	.00	.212	16963.2	.000
	.000	8495.5	.00	-8495.54	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	47.050	4073.9	12461.7	-32.12	.00	1505.572	.0	.463
	3.816	158690.1	111.58	46.34	.00	.241	13511.7	.000
	.000	9289.9	.00	-9289.88	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	47.550	3588.4	11755.0	-28.22	.00	1324.819	.0	.463
	3.352	160466.7	111.79	46.34	.00	.268	10695.0	.000
	.000	9997.8	.00	-9997.77	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

2D-POINT MASS TRAJECTORY PROGRAM ALPHA=0,LIFT=0 JOB 0022 PAGE 12

CASE 8149 FLAME FLT 00H H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC	VEL.,FT/SEC	ALTITUDE,FT	ACC.,G	THRUST,LB	DRAG,LB	ISP,SEC	S,SQFT
	MACH NO.	RANGE,FT	GAMMA,DEG	WEIGHT,LB	IT(VAC),LB-SEC	CD	Q,LB/SQFT	AE,SQFT
	TYPE	IT(DRG)	IT(THRST)	IT(T-D)	THRUST-VAC	ISP(VAC)	PC,PSF	AT,SQFT
	PC/PO	RATIO SP HT	PROP EFF	EXP RATIO	THRST COEFF	WDOT	CD-BASE	BASE AREA
5	48.050	2941.3	11145.2	-37.58	.00	1758.965	.0	.463
	2.742	161981.4	112.05	46.34	.00	.519	7325.8	.000
	.000	10926.8	.00	-10926.79	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	48.550	2410.0	10642.0	-28.75	.00	1350.082	.0	.463
	2.242	163214.0	112.37	46.34	.00	.584	4997.2	.000
	.000	11700.9	.00	-11700.94	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	49.050	2005.7	10220.4	-21.90	.00	1033.018	.0	.463
	1.863	164228.7	112.76	46.34	.00	.636	3507.2	.000
	.000	12292.2	.00	-12292.22	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	49.550	1695.8	9860.5	-16.86	.00	799.465	.0	.463
	1.573	165077.2	113.21	46.34	.00	.681	2535.7	.000
	.000	12747.6	.00	-12747.58	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	50.050	1460.6	9547.5	-12.11	.00	579.835	.0	.463
	1.353	165797.7	113.75	46.34	.00	.659	1899.7	.000
	.000	13095.6	.00	-13095.60	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	50.550	1297.0	9267.6	-8.57	.00	416.052	.0	.463
	1.201	166424.8	114.36	46.34	.00	.595	1511.1	.000
	.000	13340.7	.00	-13340.75	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

E 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

TAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
5	51.050 1.089 .000 .000	1177.5 166985.4 13522.5 .000	9009.8 115.04 .00 .000	-6.45 46.34 -13522.47 .000	.00 .00 .00 .000	318.295 .548 .000 .000	.0 1255.5 .0 .000	.463 .000 .000 .000
5	51.550 1.003 .000 .000	1085.7 167495.5 13664.7 .000	8767.5 115.77 .00 .000	-5.06 46.34 -13664.67 .000	.00 .00 .00 .000	254.626 .511 .000 .000	.0 1075.5 .0 .000	.463 .000 .000 .000
5	52.050 .934 .000 .000	1011.9 167965.4 13781.2 .000	8536.6 116.56 .00 .000	-4.16 46.34 -13781.17 .000	.00 .00 .00 .000	213.613 .490 .000 .000	.0 941.1 .0 .000	.463 .000 .000 .000
5	52.550 .877 .000 .000	950.6 168402.1 13880.0 .000	8314.3 117.40 .00 .000	-3.49 46.34 -13880.01 .000	.00 .00 .00 .000	183.148 .473 .000 .000	.0 836.2 .0 .000	.463 .000 .000 .000
5	53.050 .828 .000 .000	898.8 168810.5 13965.5 .000	8098.6 118.28 .00 .000	-2.97 46.34 -13965.49 .000	.00 .00 .00 .000	159.737 .459 .000 .000	.0 752.4 .0 .000	.463 .000 .000 .000
5	53.550 .787 .000 .000	854.4 169194.4 14040.6 .000	7888.1 119.20 .00 .000	-2.56 46.34 -14040.58 .000	.00 .00 .00 .000	141.339 .446 .000 .000	.0 684.4 .0 .000	.463 .000 .000 .000

CASE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
5	54.050	815.9	7681.5	-2.23	.00	126.597	.0	.463
	.751	169556.9	120.16	46.34	.00	.435	628.2	.000
	.000	14107.4	.00	-14107.44	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	54.550	782.3	7477.9	-1.96	.00	114.582	.0	.463
	.719	169900.3	121.15	46.34	.00	.426	581.2	.000
	.000	14167.6	.00	-14167.64	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	55.050	752.7	7276.6	-1.73	.00	104.660	.0	.463
	.692	170226.7	122.17	46.34	.00	.418	541.4	.000
	.000	14222.4	.00	-14222.37	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	55.550	726.6	7076.9	-1.53	.00	96.374	.0	.463
	.667	170537.8	123.22	46.34	.00	.410	507.5	.000
	.000	14272.6	.00	-14272.57	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	56.050	703.3	6878.4	-1.37	.00	89.400	.0	.463
	.645	170834.8	124.29	46.34	.00	.404	478.4	.000
	.000	14319.0	.00	-14318.96	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	56.550	682.5	6680.6	-1.22	.00	83.479	.0	.463
	.626	171119.0	125.38	46.34	.00	.398	453.3	.000
	.000	14362.1	.00	-14362.14	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

;E 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

TAGE	TIME,SEC	VEL.,FT/SEC	ALTITUDE,FT	ACC.,G	THRUST,LB	DRAG,LB	ISP,SEC	S,SQFT
	MACH NO.	RANGE,FT	GAMMA,DEG	WEIGHT,LB	IT(VAC),LB-SEC	CD	Q,LB/SQFT	AE,SQFT
	TYPE	IT(DRG)	IT(THRST)	IT(T-D)	THRUST-VAC	ISP(VAC)	PC,PSF	AT,SQFT
	PC/PO	RATIO SP HT	PROP EFF	EXP RATIO	THRST COEFF	WDOT	CD-BASE	BASE AREA
5	57.050	663.9	6483.1	-1.10	.00	78.411	.0	.463
	.608	171391.4	126.49	46.34	.00	.392	431.5	.000
	.000	14402.6	.00	-14402.58	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	57.550	647.1	6285.8	-.99	.00	74.047	.0	.463
	.593	171652.8	127.61	46.34	.00	.388	412.4	.000
	.000	14440.7	.00	-14440.67	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	58.050	632.0	6088.2	-.89	.00	70.272	.0	.463
	.578	171904.1	128.74	46.34	.00	.383	395.8	.000
	.000	14476.7	.00	-14476.73	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	58.550	618.4	5890.2	-.80	.00	67.001	.0	.463
	.565	172145.8	129.88	46.34	.00	.380	381.2	.000
	.000	14511.0	.00	-14511.03	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	59.050	606.1	5691.6	-.73	.00	64.156	.0	.463
	.554	172378.7	131.02	46.34	.00	.376	368.4	.000
	.000	14543.8	.00	-14543.80	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	59.550	594.9	5492.4	-.66	.00	61.668	.0	.463
	.543	172603.1	132.17	46.34	.00	.373	357.1	.000
	.000	14575.2	.00	-14575.24	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

ASE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
5	60.050	584.8	5292.2	-.60	.00	59.489	.0	.463
	.534	172819.6	133.32	46.34	.00	.370	347.2	.000
	.000	14605.5	.00	-14605.52	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	60.550	575.6	5091.1	-.54	.00	57.576	.0	.463
	.525	173028.6	134.46	46.34	.00	.367	338.4	.000
	.000	14634.6	.00	-14634.77	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
5	60.800	571.4	4990.2	-.52	.00	56.710	.0	.463
	.521	173130.4	135.03	46.34	.00	.366	334.4	.000
	.000	14649.1	.00	-14649.06	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	60.800	571.4	4990.2	-7.23	.00	367.885	.0	1.000
	.521	173130.4	135.03	46.34	.00	1.100	334.4	.000
	.000	.0	.00	.00	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	60.900	549.1	4950.5	-6.63	.00	340.171	.0	1.000
	.500	173169.9	135.26	46.34	.00	1.100	309.2	.000
	.000	35.4	.00	-35.40	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	61.100	509.8	4875.1	-5.63	.00	293.894	.0	1.000
	.464	173244.0	135.75	46.34	.00	1.100	267.2	.000
	.000	98.7	.00	-98.67	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

SE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC	VEL.,FT/SEC	ALTITUDE,FT	ACC.,G	THRUST,LB	DRAG,LB	ISP,SEC	S,SQFT
	MACH NO.	RANGE,FT	GAMMA,DEG	WEIGHT,LB	IT(VAC),LB-SEC	CD	Q,LB/SQFT	AE,SQFT
	TYPE	IT(DRG)	IT(THRST)	IT(T-D)	THRUST-VAC	ISP(VAC)	PC,PSF	AT,SQFT
	PC/PO	RATIO SP HT	PROP EFF	EXP RATIO	THRST COEFF	WDOT	CD-BASE	BASE AREA
6	61.300	476.5	4804.2	-4.82	.00	257.063	.0	1.000
	.434	173312.4	136.27	46.34	.00	1.100	233.7	.000
	.000	153.7	.00	-153.67	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	61.500	447.4	4737.2	-4.18	.00	227.289	.0	1.000
	.407	173375.9	136.82	46.34	.00	1.100	206.6	.000
	.000	202.0	.00	-202.03	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	61.700	422.3	4673.5	-3.64	.00	202.894	.0	1.000
	.384	173435.0	137.40	46.34	.00	1.100	184.4	.000
	.000	245.0	.00	-244.99	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	61.900	400.3	4612.7	-3.20	.00	182.669	.0	1.000
	.364	173490.3	138.00	46.34	.00	1.100	166.1	.000
	.000	283.5	.00	-283.50	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	62.100	380.9	4554.4	-2.83	.00	165.728	.0	1.000
	.347	173542.3	138.63	46.34	.00	1.100	150.7	.000
	.000	318.3	.00	-318.30	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	62.300	363.6	4498.3	-2.51	.00	151.407	.0	1.000
	.331	173591.1	139.28	46.34	.00	1.100	137.6	.000
	.000	350.0	.00	-349.98	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

ASE 8149 FLAME FLT 006 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
6	62.500	348.6	4444.1	-2.24	.00	139.204	.0	1.000
	.317	173637.3	139.95	46.34	.00	1.100	126.5	.000
	.000	379.0	.00	-379.02	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	62.700	334.9	4391.5	-2.00	.00	128.729	.0	1.000
	.305	173680.9	140.64	46.34	.00	1.100	117.0	.000
	.000	405.8	.00	-405.79	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	62.900	322.7	4340.4	-1.80	.00	119.680	.0	1.000
	.293	173722.3	141.34	46.34	.00	1.100	108.8	.000
	.000	430.6	.00	-430.62	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	63.100	311.7	4290.7	-1.52	.00	111.818	.0	1.000
	.283	173761.6	142.06	46.34	.00	1.100	101.7	.000
	.000	453.8	.00	-453.76	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	63.300	301.7	4242.0	-1.47	.00	104.951	.0	1.000
	.274	173799.0	142.80	46.34	.00	1.100	95.4	.000
	.000	475.4	.00	-475.42	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	63.500	292.7	4194.5	-1.33	.00	98.926	.0	1.000
	.266	173834.6	143.54	46.34	.00	1.100	89.9	.000
	.000	495.8	.00	-495.80	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

8149 FLAME FL1 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

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AGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
6	63.700	284.6	4147.8	-1.21	.00	93.616	.0	1.000
	.259	173868.6	144.29	46.34	.00	1.100	85.1	.000
	.000	515.0	.00	-515.04	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	63.900	277.2	4102.0	-1.10	.00	88.920	.0	1.000
	.252	173901.0	145.05	46.34	.00	1.100	80.8	.000
	.000	533.3	.00	-533.29	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	64.100	270.4	4056.9	-1.00	.00	84.751	.0	1.000
	.246	173932.1	145.82	46.34	.00	1.100	77.0	.000
	.000	550.7	.00	-550.65	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	64.300	264.2	4012.5	-.91	.00	81.040	.0	1.000
	.240	173961.8	146.56	46.34	.00	1.100	73.7	.000
	.000	567.2	.00	-567.23	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	64.500	258.6	3968.7	-.84	.00	77.729	.0	1.000
	.235	173990.3	147.35	46.34	.00	1.100	70.7	.000
	.000	583.1	.00	-583.10	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
6	64.700	253.5	3925.4	-.76	.00	74.766	.0	1.000
	.230	174017.7	148.12	46.34	.00	1.100	68.0	.000
	.000	598.3	.00	-596.34	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

-ASE 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

STAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
6	64.800	251.1	3903.9	-.73	.00	73.401	.0	1.000
	.228	174030.9	148.50	46.34	.00	1.100	66.7	.000
	.000	605.8	.00	-605.75	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	64.800	251.1	3903.9	-7.07	.00	367.008	.0	1.000
	.228	174030.9	148.50	46.34	.00	5.500	66.7	.000
	.000	.0	.00	.00	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	68.700	92.4	3453.2	-.11	.00	50.386	.0	1.000
	.084	174219.3	168.93	46.34	.00	5.500	9.2	.000
	.000	396.8	.00	-396.76	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	72.700	88.3	3097.6	-.01	.00	46.559	.0	1.000
	.080	174256.3	177.36	46.34	.00	5.500	8.5	.000
	.000	586.8	.00	-586.76	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	76.700	87.8	2745.4	-.00	.00	46.494	.0	1.000
	.079	174264.8	179.39	46.34	.00	5.500	8.5	.000
	.000	772.8	.00	-772.77	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	80.700	87.4	2395.1	-.00	.00	46.495	.0	1.000
	.079	174266.7	179.86	46.34	.00	5.500	8.5	.000
	.000	958.8	.00	-958.75	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

E 8149 FLAME FLT 008 H=55275 FT,V=1240 FPS,GAMMA=+31.1 DEG,26.2 SEC COAST, PDA PANNEL CD 5/3/76

TAGE	TIME,SEC MACH NO. TYPE PC/PO	VEL.,FT/SEC RANGE,FT IT(DRG) RATIO SP HT	ALTITUDE,FT GAMMA,DEG IT(THRST) PROP EFF	ACC.,G WEIGHT,LB IT(T-D) EXP RATIO	THRUST,LB IT(VAC),LB-SEC THRUST-VAC THRST COEFF	DRAG,LB CD ISP(VAC) WDOT	ISP,SEC Q,LB/SQFT PC,PSF CD-BASE	S,SQFT AE,SQFT AT,SQFT BASE AREA
7	84.700	86.9	2046.5	-.00	.00	46.493	.0	1.000
	.078	174267.1	179.96	46.34	.00	5.500	8.5	.000
	.000	1144.7	.00	-1144.73	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	88.700	86.5	1699.7	-.00	.00	46.496	.0	1.000
	.078	174267.2	179.96	46.34	.00	5.500	8.5	.000
	.000	1330.7	.00	-1330.71	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	92.700	86.0	1354.8	-.00	.00	46.494	.0	1.000
	.077	174267.4	179.96	46.34	.00	5.500	8.5	.000
	.000	1516.7	.00	-1516.69	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	96.700	85.6	1011.5	-.00	.00	46.492	.0	1.000
	.077	174267.5	179.96	46.34	.00	5.500	8.5	.000
	.000	17[illegible].7	.00	-1702.66	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	100.700	85.2	670.0	-.00	.00	46.495	.0	1.000
	.076	174267.7	179.96	46.34	.00	5.500	8.5	.000
	.000	1888.6	.00	-1888.64	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000
7	104.700	84.7	330.2	-.00	.00	46.493	.0	1.000
	.076	174267.9	179.96	46.34	.00	5.500	8.5	.000
	.000	2074.6	.00	-2074.61	.00	.000	.0	.000
	.000	.000	.000	.000	.000	.000	.000	.000

APPENDIX B

VEHICLE FLIGHTS 07 AND 08
PLANNING DATA

APPENDIX B

VEHICLE FLIGHTS 07 AND 08 PLANNING DATA

I. COMMAND IGNITION STUDY

A. DISCUSSION

The major method of controlling the trajectory of the unguided FLAME vehicle is through ignition conditions, and stage timing. With stage timing relatively fixed for a given system (variable only in chamber pressure based staging switch functioning), the major control function is then first stage ignition conditions. The timing graphs are included here as Figures 1 and 2 for reference purpose.

Using aircraft release conditions, as determined by real-time display of tracking radar data, and a graphic chart relating those drop conditions to first stage ignition time to achieve a given ignition flight path pitch angle was selected as the technique for TTR operations 07 and 08. This is in lieu of the preferred methods of computerizing the procedure as was done at WOPS. This procedure becomes extremely critical at TTR since local ground elevation ranges between 5200 and 7200 feet vs sea level at WOPS; i.e., there is little margin for error in performing the FLAME experiments, and completing recovery sequence before impacting the ground, particularly after going to the staged recovery chute.

Since the flight experience before 05 and 06 indicated a consistent terminal velocity of 13,200 fps rather than 13,600, a brief examination was made of velocity-time histories. This examination indicated that the loss was principally in the first stage. In fact the best velocity time match required a 50% increase in drag during both the coast phase following a/c release,

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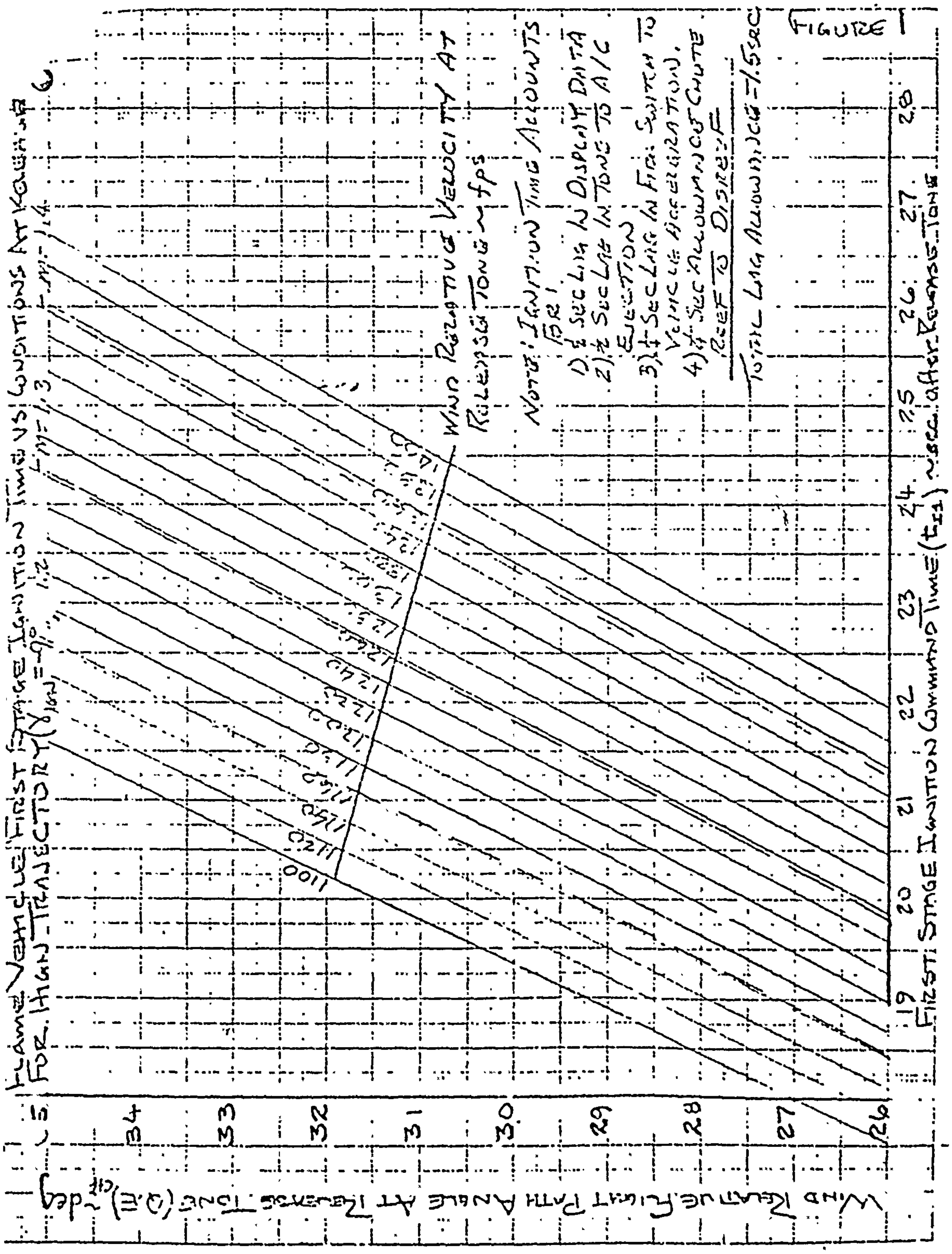

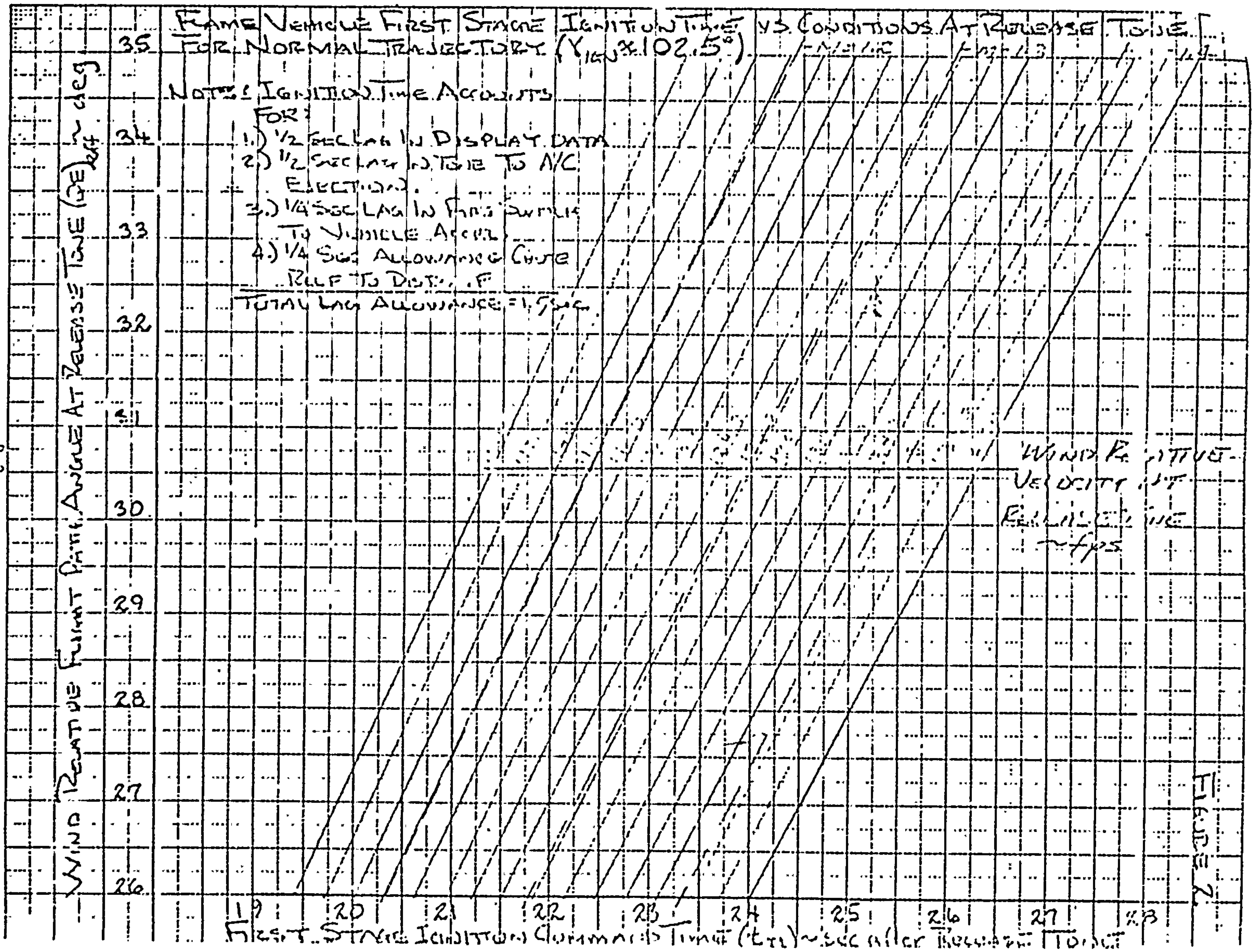
RAME VEHICLE FIRST STAGE IGNITION TIME VS CONDITIONS AT RELEASE TIME
FOR NORMAL TRAJECTORY ($\gamma_{IGN} \approx 102.5°$)
NOTES: IGNITION TIME ACCOUNTS FOR:
1.) 1/2 SEC LAG IN DISPLAY DATA
2.) 1/2 SEC LAG IN TIME TO A/C EJECTION.
3.) 1/4 SEC LAG IN FIRING SWITCH TO VEHICLE ACCEL.
4.) 1/4 SEC ALLOWANCE CHUTE RELF TO DIST.
TOTAL LAG ALLOWANCE = 1.5 SEC.
WIND RELATIVE VELOCITY AT RELEASE TIME ~ fps
WIND RELATIVE FLIGHT PATH ANGLE AT RELEASE TIME (γ_E)$_{REL}$ ~ deg
35
34
33
32
31
30
29
28
27
26
19
20
21
22
23
24
25
26
27
28
FIRST STAGE IGNITION COMMAND TIME (t_{FI}) ~ sec after Release Time
FIGURE 2

I, A, Discussion (cont.)

and during first stage burn. This fact directly affects the first stage timing since the rate of change of flight path is inversely proportional to velocity; i.e., a lower velocity during this critical time could cause a lower than planned ignition angle which, at TTR, could be fatal. The most complete set of data available is that from Flight 02, which was flown at TTR, and resulted in excellent optical and radar trajectory definition. These data along with weight adjustments as data accumulated, were used to adjust the computer model used for trajectory simulation (2-degrees of freedom). The resultant comparison of essential trajectory components is illustrated in Figure 3. Also shown on Figure 3 are the results of applying the timing graphs to Flight 02. The -9° timing point indicate the results of Figure 1 would have resulted in ignition at -9° (all delays being as anticipated). The -12.5° timing point from Figure 2 would have resulted in actual ignition between -12.3° and -13.0° depending upon use of radar or optical data. Further, and as important, the other two trajectory elements also agree very well. Thus, it is judged that the computer model, gives results consistent with the best current data base (Flight 02), and is an adequate basis for the timing function graphs (and for a computer based system if adopted in the future).

More important to the FLAME experimentation is final burnout conditions. Thus a brief examination of actuals to date versus computer simulation does indicate a final burnout altitude of 0 ≈ 3,000 feet high and flight path angle about 0° ≈ 2° high. The timing of the charts could probably be extended about 1/2 sec for average condition; however for TTR manual operations it is not recommended.

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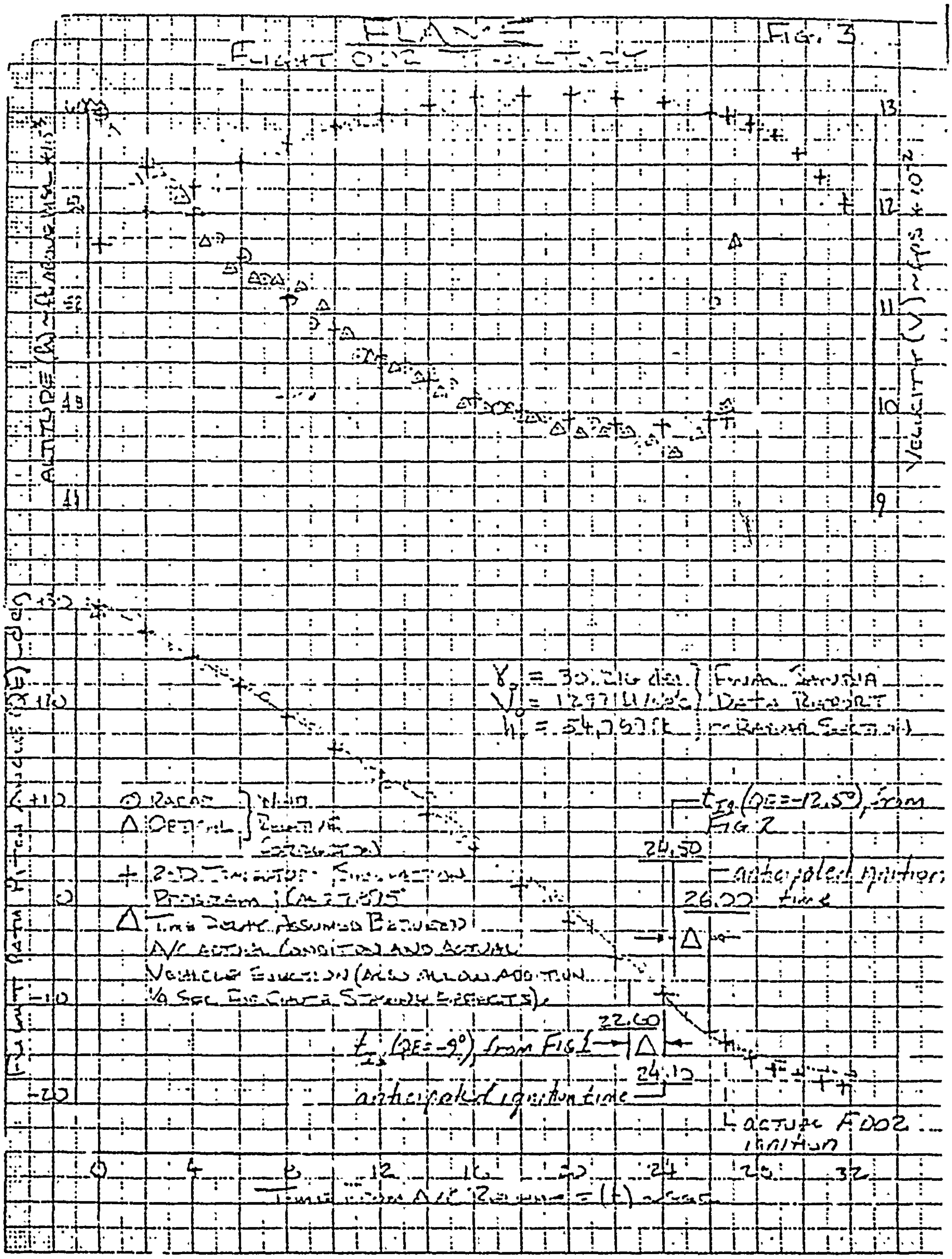

APPENDIX B

II. FLAME VEHICLE FIRST-STAGE COMMAND IGNITION PROCEDURE

A. INTRODUCTION

The primary objective of FLAME vehicle Flights 07 and 08 is to obtain a full system functional test from aircraft drop through successful payload recovery. To do this at Tonopah Test Range, with its relatively high ground elevations, it may be deemed necessary to fly a conservative trajectory; i.e., perform all system functions at higher-than-normal altitudes, with some margin, to insure full recovery system functioning before ground impact. Figure 1 is provided for this case. If nominal operation is desired, Figure 2 should be used.

With this objective in mind, and the experience of six live tests to date, the following paragraphs detail the suggested operational procedure for igniting first stage (the principal mode of trajectory control) to obtain a trajectory which will give a very high probability of vehicle release from the aircraft, and a safe subsequent trajectory.

B. DISCUSSION

Experience to date, indicating the mode of delivery of the flight vehicle to its launch condition by the carrier aircraft, is highly satisfactory, particularly when wind field effects are included.

Contrariwise, experience to date in igniting first stage, the primary method of trajectory control, has not been as good. This is largely due to jitter in the "instantaneously displayed" radar derived data, principally

II, B, Discussion (cont.)

flight path angle, the most important trajectory shaping parameter. Fortunately, in the operations to date, the aircraft has launched the vehicle at very near nominal condition such that last instant change from radar displayed flight path angle to a nominal ignition time base has proved satisfactory, so much so that the following suggested procedure reverses this roll; i.e., base first-stage ignition on time after drop tone, dependent on aircraft flight conditions, with radar display as confirmation/back-up input.

The basic plotted data attached reflects data-set updating based on the six flights to date, principally 02 at TTR. Lag times are taken from the data tapes at TTR.

C. SUGGESTED FIRST STAGE IGNITION PROCEDURE FOR FLIGHTS 07 AND 08

The ignition switch controller should have at least two assistants with single functions assigned during aircraft pull-up maneuver. The following should be accomplished in 15.0 seconds or less.

1. A time display, in seconds should be initiated by the release tone. A stop watch, should be available as a back-up.

2. Assistant a) focus completely on read-out of velocity at release tone.

3. Assistant b) focus completely on read-out of flight path angle at bomb tone.

4. Assistants a) and b) record immediately the values observed.

II, C, Suggested First Stage Ignition Procedure for Flights 07 and 08 (cont.)

5. Assistant a) will go to attached curve at indicated flight path angle and velocity (both wind relative) and determine proper ignition time, in seconds after release tone, and give verbally to ignition controller, then record.

During final aircraft maneuver, the ignition switch controller, should visually follow the plot board display, for orientation purposes. At release tone, the ignition controller's attention should be split between the plot board and the timer display, updating his orientation. Before flight, the controller should review and have in mind his nominal conditions at drop tone.

1. Velocity $\approx$ 1270 ft/sec
2. γ $\approx$ 30 degrees
3. Nominal Ignition $\approx$ 23 seconds after release tone for Figure 1 (conservative trajectory), and 24.5 seconds after release tone for a nominal trajectory (Figure 2).

While these values are nominal, the ignition controller should be prepared for significantly different values since the attached plot will effectively achieve the desired trajectory for a wider range of drop conditions. The only purpose of the ignition operator performing the foregoing tasks is to get himself oriented.

Thus, if a shorter time is called for by his timing assistant, this plot board should confirm, lower angle and/or lower than nominal velocity

II, C, Suggested First Stage Ignition Procedure for Flights 07 and 08 (cont.)

drop. Conversely, a longer time should confirm a higher angle and/or higher velocity drop.

For reference, to date the aircraft has tended to the high side in both velocity and angle. The range plot board operator can assist the ignition controller with several verbal inputs about relative appearance of aircraft release and early vehicle coasting trajectory; i.e., near nominal, hot/high, slow/low, etc. Perhaps low voice level comments on angle approaching fire-switch would help also.

The ignition control then has three potential sources of input on which to make his decision.

1. V- γ plot board displays from aircraft pull up through rocket coast.
2. Trajectory quality from range plot board operation.
3. Ignition time from assistant.

Timewise he is getting items 1 and 2 continually. Item 3 he will get by 15.0 seconds after drop tone.

In terms of precedence the order should be:

1. Time ignition
2. V- γ plot board
3. Range plot board
4. Nominal time

II, C, Suggested First Stage Ignition Procedure for Flights 07 and 08 (cont.)

In the final analysis, in case of a data system failure of any channel, the ignition switch operator must quickly access the quality of the inputs and act accordingly.

For future flights, consideration should be given to a specifically developed computer command system with manual, parallel, back-up. All of the above are of course backed by an on-board timer; however, its functioning is total dependent on a hot/high trajectory at TTR.

III. OPERATIONS PLAN - FLIGHTS 07 AND 08

A. DESIGNATION AND LAUNCH SCHEDULE (DATES TENTATIVE)

Payload F07 - 14 Jan (at Release Point 142400Z Jan)
Payload F08 - 15 Jan (at Release Point 152400Z Jan)

B. TRACKING INFORMATION

1. Azimuth: 006.6 degrees (true). (Reference is Beatty VOR radial heading of 352°). Release point coordinates are latitude 37.370°, longitude 116.6494°.

III, B, Tracking Information (cont.)

2. Beacon Information

	Vehicles F07/F08	Aircraft
Location	Payload	--
Frequency:		
Transmit	5763.4 MHz	5765 MHz
Receive	5690 MHz	5690 MHz
Sensitivity	-41 db	-70 db
Pulse Width	0.4 μ sec	0.5 μ sec
PRR	2500 pps	Adjustable - 1000-2600 pps
Peak Power	5.2 watts	600 watts
Double Pulse Spacing	8.0 μ sec	8.0 μ sec
Delay	2.0 μ sec	2.0 μ sec
Type	Vega 228C	Vega 302C

3. Aircraft Beacon

Use for initial acquisition and track until acquisition of vehicle beacon. Aircraft beacon and external power on vehicle should be functional at takeoff. Aircraft beacon is OFF at direction of TTR control.

4. Track on vehicle beacon only, once acquisition is obtained. Any change back to aircraft beacon will be directed by TTR.

III, Operations Plan - Flights 07 and 08 (cont.)

C. PLOT BOARD DATA

1. Right Plot Board

X-Y plot - azimuth ground track

X-H plot - ground range vs altitude

Nixie tube - altitude

Nixie tube - velocity (fps) (ground relative)

2. Left Plot Board (with release criteria pre-plot)

Vel (ground relative) vs γ

Altitude vs Vel (ground relative)

3. Balloon data will be obtained prior to flight time. Based on this data, range personnel will input this data into the plot board pre-plots to insure air relative release criteria is correlated to ground relative radar track data.

4. Release Criteria

Velocity - Mach 1.3 $\pm$ 0.2 (air relative)

Altitude - 55,000 ft (MSL) $^{+2000\text{ ft}}_{-1000\text{ ft}}$

$\gamma = 30°$ (air relative) $\pm 2°$

Payload/Vehicle Telemetry - Functional (prior to takeoff, 50% of the strain gages and thermocouples must be operational)

Beacon track acquisition

Command receiver operational

III, Operations Plan - Flights 07 and 08 (cont.)

D. VEHICLE PERFORMANCE/RECOVERY

1. These vehicles have a command receiver for control room command fire. The receiver is identical to that previously used. Specifications and technical characteristics are provided by enclosure. Frequency of this receiver is 412.0 MHz. Operational channels are:

Channel 4 - monitor
Channels 1 and 2 - command fire channels

2. Nominal command fire angle is minus 12.4 $\pm$ 0.5 degrees (air relative).

3. Back-up manual command fire information based on time-from-release will be provided.

4. A back-up manual Raymond timer is set for 27.25 seconds after release.

5. Payload experiment time after second stage burnout/separation is 3.75 seconds.

6. Due to proximity to the command center for nominal flight, recovery is planned by vehicle. In case of anamolous flight, a helicopter will be used as backup. If a helicopter is obtained for personnel transport, it may be made available for rapid recovery.

III, Operations Plan - Flights 07 and 08 (cont.)

E. COMMUNICATIONS/AIRCRAFT TRACK

1. Frequencies for control of the F-4J are:

	F-4J
Primary	257.0 MHz
Alternate	384.8 MHz

2. An open telephone line will be established with China Lake Naval Air Station prior to aircraft takeoff. Range readiness will be confirmed prior to aircraft takeoff. DNA will provide telephone numbers to TTR for this telephone link.

3. Call signs are: F-4J - FLAME 1
TTR Control - SILVER BOW

F. RADAR DATA/TELEMETRY/PHOTO RECORD

1. The tape and oscillographic formats are provided by enclosure. Note that a replay is requested by PDA so that an oscillograph record can be obtained at 100 mm/sec.

2. The instructions on handling the data post-event have been provided. Both PDA and ALRC will receive the telemetry tapes and oscillograph records. Aircraft and vehicle performance reports will be provided according to the distribution list attached as an enclosure.

III, F, Radar Data/Telemetry/Photo Record (cont.)

3. Ground and aerial photography must be printed as soon as possible for post-flight analysis. DNA will provide distribution information.

4. Payload S-band telemetry frequency is 2275.5 MHz for payload F07. There is no telemetry on payload F08. Recession data on this vehicle is obtained from recovery.

5. Vehicle performance P-band telemetry frequency for Vehicle F07 is 240.2 MHz. There is no vehicle telemetry on Vehicle F08.

6. Request that digitized data tapes be provided to PDA.

7. Radar track of the PEDRO to impact is desired for both flights to assist in post-flight recovery of the spent motor.

G. FLIGHT SIMULATIONS/DRY RUNS

1. Simulations similar to previous operation will be scheduled prior to all flights.

2. There are F-4J dry runs scheduled for 13 January 1976.

H. PHOTOGRAPHIC COVERAGE

1. Photo camera location planning should provide layout which best covers the flight sequencing, particularly during the payload free-flight

III, H, Photographic Coverage (cont.)

from 36,000 ft to parachute deployment. Maximum coverage is necessary for the heat shield jettison at 22,000 ft through parachute deployment.

2. The vehicle should have both stages painted flame orange with three fins painted the same orange and one fin black. In the same quadrant as the black fin there should be a black axial stripe on the body of the PEDRO.

I. FLIGHT SEQUENCING CHECKS (IN-BOUND)

1. At takeoff have TLM external on (vehicle beacon ON) and ground command transmitter ON to capture command receiver.

2. Have aircraft beacon ON at takeoff for acquisition.

3. During acceleration run at 40 Kft, there is a bomb tone and command receiver check. Actions required are:

a. Have ground command transmitter ON.

b. Tone 4 check ON.

c. Pilot confirm receipt of signal by monitor light.

d. Tone 4 OFF.

e. Pilot confirm monitor light OFF.

f. Tone 4 ON. Remain ON, pilot confirm monitor light ON. This monitor light should remain on for the remainder of the flight.

g. Release bomb tone check follows command receiver check. Pilot confirm bomb tone.

III, Operations Plan - Flights 07 and 08 (cont.)

J. FLIGHT PROFILE COMMANDS

A summary of flight profile commands follows:

1. Provide time hacks to climb (from -15 seconds, -10 seconds, 9, 8, ... 1). Give climb command.

2. Provide similar time hacks to 2g pull-up (-15 seconds, -10 seconds, etc.).

3. At -15 seconds to pull-up, give command for final arm/ internal TLM. Pilot confirm ARM/TLM Int. (IMPORTANT: Pilot must not go to INT TLM prior to -15 sec to pull-up on payload F07 since this payload has a thermal battery activated by internal TLM ON and has a limited life of approximately 150 seconds). Payload F08 has a NiCd battery with a lifetime of approximately 3 minutes.

4. The control room will indicate on the plot board a minimum acceptable velocity at -15 seconds to pull-up in order to give the ARM command for payload F07. This is essential due to the limited battery life after internal power.

5. The TLM room will confirm acceptable telemetry to the control room on payload F07.

6. The control room will count down to release with READY-READY.

III, J, Flight Profile Commands (cont.)

7. Vehicle release will be by bomb tone followed by voice command. Under no circumstance should the pilot release the vehicle without receipt of at least one of these commands.

8. Radar track (and plot board) continues on vehicle. The command receiver tones will be given from control room in sequence Tone 1 - Tone 2. The radar plot will have a pre-plot "anticipation command" angle since there is a radar delay to actual plot.

K. VEHICLE IGNITION COMMAND PROCEDURES

1. The left plot board data display of velocity-angle and velocity-altitude is not required. Computer capacity for CRT display and automated command fire has taken all memory space and analog display of v-angle and v-altitude is not possible on the left plot board. However, the CRT display is an improved display of the same information (FLAME Tracking Data) and replaces the plot board data.

2. Computer capability for the limits is:

Altitude	= 54,000 to 56,000 ft
Velocity	= 1160 to 1360 fps (Mach 1.21 to Mach 1.42 approximately)
Release Angle	= +28 to +32 degrees

These limits will provide an asterisk on the CRT and allow computation of a fire time for automatic command fire. For allowable release conditions outside these computer limits manual fire after table look-up is required.

III, K, Vehicle Ignition Command Procedures (cont.)

3. Manual nomograph timing based on table look-up will be accomplished in all cases, even if release asterisks appear on the CRT. This accomplishes manual override. If computer timing computations appear this time-to-fire will take precedence over table look-up and manual firing accomplished only if automatic command fails.

4. The data displays will correlate to air relative conditions based on the latest weather balloon data.

5. For final aircraft maneuver prior to release, and after vehicle release the velocity - angle - altitude plot board is activated. The range controller will follow this plot for orientation and performance purposes to demonstrate vehicle attitude as a correlation with the timer.

6. The timing nomograph provides reaction time lags based on flight data experience as shown:

a. 0.5 sec lag in data display.

b. 0.5 sec lag in tone-to-aircraft vehicle ejection pilot reaction time.

c. 0.25 sec lag in fire switch to vehicle acceleration.

FLAME TRACKING DATA TIME 17 29 41

RADAR	VALID	X-EAST (Feet)	Y-NORTH (Feet)	H MSL (Feet)	TOTAL VEL (Ft/Sec)	PATH ANGLE (Degrees)
R36	*	28076	-183180	57002	1242*	29.32*

RELEASE CONDITIONS

TIME (Min,Sec)	H MSL (Feet)	TOTAL VEL (Ft/Sec)	PATH ANGLE (Degrees)
29 38.0	54904	1322	28.95

TIMING COMPUTATIONS

DELAY TIME (Sec)	FIRING TIME (Min,Sec)	COUNTDOWN TO FIRE (Sec)
24.2	30 2.2	-21.1

APPENDIX B

MCR-151 TEN-CHANNEL
COMMAND RECEIVER TECHNICAL CHARACTERISTICS

Frequency Range	406 to 450 MHz (Oper Freq 412.0 MHz)
Frequency Deviation	± 50 KHz per channel
Threshold Sensitivity	2 microvolts
Maximum Usable RF Input	2 volts RMS
Antenna Impedance	50 ohms
Oscillator Stability	± 0.002%
Tuning	Crystall controlled
RF Bandwidth (-6 db)	650 KHz minimum
RF Bandwidth (-60 db)	2500 KHz maximum
Electromagnetic Interference Suppression	MIL-I-6181D, MIL-I-26600
Noise Figure	8 db
Number of Channels	4-10
Type of Output	Relay contact, 2 amperes resistive at 23 VDC
Decoder Filter BW (-2 db)	± 1%
Decoder Filter BW (-20 db)	± 3% Minimum
Input Voltage	+22 to +36 VDC
Input Power (+28 VDC)	2.4 watts standby plus 0.9 watts per relay operated
Telemetry Output Signal Strength	0 to 5.0 VDC for RF signals between 1 and 1000 microvolts
Operating Temperature	-54°C to +85°C
Vibration	20g, 30 to 2000 Hz Sinusoidal
Shock	100 g for 1 millisecond
Altitude	Unlimited
Pressurization	Unit Sealed
Volume (less connectors and mounting feet)	37 in 3
Weight	41 oz

IV. TELEMETRY DATA

A. VEHICLE PERFORMANCE TELEMETRY (F07) (P-BAND)

1. Tape Recorder Format

Track	
1	IRIG Time Code
2	Video
3	100 KHz Reference
4	Pre-D Cal
5	Video
6	N/A
7	Voice

2. Analog Recorder

a. Recorder Calibration - LBE - 0%
CF - 50%
UBE - 100%

b. Oscillograph Print Speed - 20 mm/sec
(Note: A playback print at 100 mm/sec may be requested).

c. Print record during flight will produce IRIG Channels 4 thru 17 and multiplexed Channel 18. Channel 18 data will display 16 de-multiplexed data channels with replay producing other 9 channels.

d. Two replays are required to print Channel 19 de-multiplexed data.

APPENDIX B

IV, A, Vehicle Performance Telemetry (F07) (P-Band) (cont.)

e. Channel Assignments

IRIG Channel	Function	Specification
4 (0.96 KHz)	Pitch Accel (±5g)	50% ± 3%
5 (1.30 KHz)	Yaw Accel (±5g)	50% ± 3%
6 (1.70 KHz)	Axial Accel (0 to +35g)	50% ± 3%
7 (2.30 KHz)	Nozzle Strain	50% ± 3%
8 (3.00 KHz)	Nozzle Strain	50% ± 3%
9 (3.90 KHz)	Nozzle Strain	50% ± 3%
10 (5.40 KHz)	Nozzle Strain	50% ± 3%
11 (7.35 KHz)	Nozzle Strain	50% ± 3%
12 (10.50 KHz)	Nozzle Strain	50% ± 3%
13 (14.50 KHz)	Nozzle Strain	50% ± 3%
14 (22.00 KHz)	Nozzle Strain	50% ± 3%
15 (30.00 KHz)	Nozzle Strain	50% ± 3%
16 (40.00 KHz)	Nozzle Strain	50% ± 3%
17 (52.50 KHz)	Motor Head Pres. (0 to +1000 psi)	5 ± 3%
18 (70.00 KHz)	25 Thermocouples (MPX) (-60°F to +300°F)	45 ± 3%
19 (93.00 KHz)	Breakwire Grid (MPX) (0 to +5v)	100% ± 3%

3. Frequency

240.2 MHz

IV, Telemetry Data (cont.)

B. PAYLOAD TELEMETRY (F07) (S-BAND)

1. Tape Recorder Format

Track	
1	IRIG Time Code
2	Video
3	100 KHz Reference
4	Pre-D Cal
5	Video
6	N/A
7	Voice

2. Analog Recorder

a. Recorder Calibration - LBE - 0%
CF - 50%
UBE - 100%

b. Oscillograph Print Speed - 20 mm/sec
(Note: A playback print at 100 mm/sec is required).

IV, B, Payload Telemetry (F07) (S-Band) (cont.)

c. Channel Assignments

IRIG Channel	Function	Specification
10 (5.4 KHz)	Axial Accel (±200g)	50% ± 3%
11 (7.35 KHz)	Pitch Accel (±100g)	50% ± 3%
12 (10.5 KHz)	Yaw Accel (±100g)	50% ± 3%
15 (30.0 KHz)	Roll Rate Magnetometer	50% ± 3%
E (70.0 KHz)	Axial Accel (+200/-400g)	67% ± 3%

3. Frequency

2275.5 MHz

APPENDIX C

FLAME VEHICLE
SEQUENCE OF EVENTS

17 July 1974
Revised: 18 Feb. 1975

FLAME SEQUENCE OF EVENTS

Time From Release	Interval Time	Event Number	Remarks
90 sec	90 sec	1	Pilot Arms Sequencer. Safe light goes "off". Arm light goes "on". Payload TLM goes to "Internal power". Final Aircraft Maneuver in progress.
T+0	0.5 sec	2	Vehicle Release from Aircraft. Timers M1, M5 and M2 start. Timers M1, M5 and M2 running.
T+0.5	1.9	3	Fin Release (M2). Timers M1 and M5 running.
T+2.4	1.4	4	M1A and M5A Timer contacts operate (ARM interlock). Timers M1 and M5 running.
T+3.8	16.2	5	M1B and M5B Timer contacts operate. M1B contact enables Fin Malfunction Safe interlock for approximately 4.6 seconds. Timers M1 and M5 running.
T+20.0	5.7	6	Pedro Arm (M5C). Timers M1 and M5 running.
T+25.7	1.55	7	Nominal Pedro ignition time (via command receiver). Pedro P_c switch operates. Timers M1 and M5 running.
T+27.25	2.75	8	Pedro backup ignition (M1C). Timers M1 and M5 running.
T+30.0	6.7	9	M1D and M5D Timer contacts operate. Arms recruit firing circuit. Pedro burn continuing.
T+36.7	0	10	Pedro Burn Out; Pedro P_c switch operates.

Time From Release	Interval Time	Event Number	Remarks
T+36.7		11	Recruit Ignition; stage separation; recruit P_c switch operates; Timer M3 starts to run; Payload Parachute Time Delay Initiator energized; Timer M4 starts to run.
	0.5		Timers M3 and M4 running.
T+37.2		12	Payload Delay Detonator Energized (M3); Payload Separation Armed.
	0.5		Timer M4 running.
T+37.7		13	Payload Cable Cutter Operates (M4).
	1.0		Recruit burn continuing.
T+38.7		14	Recruit Burnout; Recruit P_c switch operates; Payload Separation Initiators energized.

APPENDIX D

OPTIMIZED FLAME VEHICLE
PRELIMINARY DESIGN

OPTIMIZED FLAME VEHICLE
PRELIMINARY DESIGN

I. INTRODUCTION

The original desired reentry conditions for the FLAME vehicle design was to subject a 50-lb payload to 15,000 fps at 32,000 ft. No reentry angle (γ) was specified; however, a gamma range of 18°-20° was eventually established.

A baseline decision was made to use an F-4 aircraft because of its performance at altitude capability, its water line height off the deck, and its availability.

Another important constraint was the requirement to use existing Government-furnished motors (to satisfy program schedule and cost constraints).

The vehicle baseline design (the FLAME vehicle as it exists today) utilizes the Pedro and Recruit motors. Early trajectory analyses indicated this vehicle configuration would meet the above criteria; however, a number of problems evolved during the design evolution that negated the possibility of reaching the desired reentry conditions. The problems centered around weight and drag increases as follows:

a. To achieve the required stability during first-stage burn, the fins were too large to maintain adequate ground clearance under the aircraft. This resulted in a fin rotation system that increased weight.

b. The payload weight increased from 50 lb to 75-83 lb.

c. The vehicle was mounted on the aircraft offset in pitch and yaw to allow for adequate nose wheel clearance during retraction.

I, Introduction (cont.)

d. The nozzle weight increased because of its redesign (applicable to Flights 07 and 08).

e. Vehicle telemetry and command systems were included on most flights.

Upon realization of the performance problem, an alternate second motor was examined (Sprint second stage). This proved to no avail, however, because of stability problems inherent to the Sprint motor geometry and the excessive cost associated with use of the Sprint active control system.

Because of the above, the FLAME vehicle performance criteria was revised to:

o	Payload weight:	75 lb
o	Reentry altitude:	38,000 ft
o	Reentry gamma:	18°-25°
o	Reentry velocity:	13,250 fps

All FLAME vehicle flights met or slightly exceeded the revised criteria.

Because of the necessary performance reduction, a low-level design program was initiated, concurrent with fabrication and flight of the FLAME vehicles, to optimize the vehicle to meet the original design parameters. That which evolved follows. For simplicity, it has been identified as the "Super FLAME" vehicle.

II. SUMMARY

The Super FLAME design uses the FLAME concept, in that it is an aircraft-launched test vehicle that is cost effective, reliable, versatile, and has a quick reaction capability.

The design utilizes FLAME component designs to a great extent to minimize development costs and to take advantage of existing tooling and hardware.

Because of the evolution of aircraft availability within the last two years, and because of the design constraints imposed on the vehicle by the F-4, the Super FLAME has been designed using the USAF F-15 as the baseline aircraft. Studies show, however, that the F-111 will handle the vehicle equally as well. In addition, the F-14 could most likely be utilized.

The Super FLAME mounts to the inboard wing pylon rather than being belly-mounted as on the F-4. This makes things simpler, as more volume is available for the vehicle envelope. The fins no longer need to be rotated, thus creating a considerable weight and cost decrease. In fact, the recurring costs of the Super FLAME are similar to those of the FLAME vehicle in spite of an increased second-stage motor cost.

The first-stage motor configuration is identical to the Pedro (TX-261-3) motor. The case would most likely be a residual TX-261-3 (Pedro), as a number of these are on "hold" by Huntsville Arsenal for the Super FLAME program. The motor would be loaded with HTPB propellant. The Pedro nozzle, as flown on FLAME Flights 07 and 08, was designed using Super FLAME performance criteria, thus is readily adaptable.

The second-stage motor will be new. It will be 15 in. in diameter and 125 in. long, and will be flare stabilized as in FLAME. This configuration is the result of a trade-off study performed, a discussion of which appears in Paragraph III.B. The motor case will be thermally protected with a fiberglass shroud. A design specification for this motor appears in the following Design section (III.C.4.).

The payload separation system has been redesigned to eliminate use of the separation clamp, thus making the aerodynamic surface at the payload/

vehicle interface smooth. The proposed system can be modified to accept a number of payload base diameters ranging from 9 in. to 15 in. in diameter. The system has been optimized taking efficiency, weight, and performance into account.

The Super FLAME performance will approach the following desired parameters when used in a reentry-type application:

o	Velocity:	∿17,000 fps
o	Altitude:	37,000 ft
o	Gamma:	23°
o	Payload weight:	75 lb

III. DESIGN

A. GENERAL

The Super FLAME vehicle is a two-stage solid rocket designed to mate with the LAU-77A launcher (standard launcher that adapts to the bomb rack on the F-15, F-111, etc.). The design envelope is based on the F-15 aircraft (see Figure D-1); however, it also can be accepted on the F-111. The total length is 335.2 in. with a 9-in. base diameter payload, or 337.2 in. with a 15-in. base diameter payload. The nominal weight is 4,847 lb, less payload.

The flight scenario is identical to FLAME (for reentry nosetip testing), in that the vehicle coasts to apogee upon aircraft release. The experiment period commences at payload separation.

The electronics are the same; however, it is recommended that the gyro platform, as discussed in Section III.C.6., be used for stage initiation (fire at predetermined gamma). This would negate those problems encountered on Flights 07 and 08.

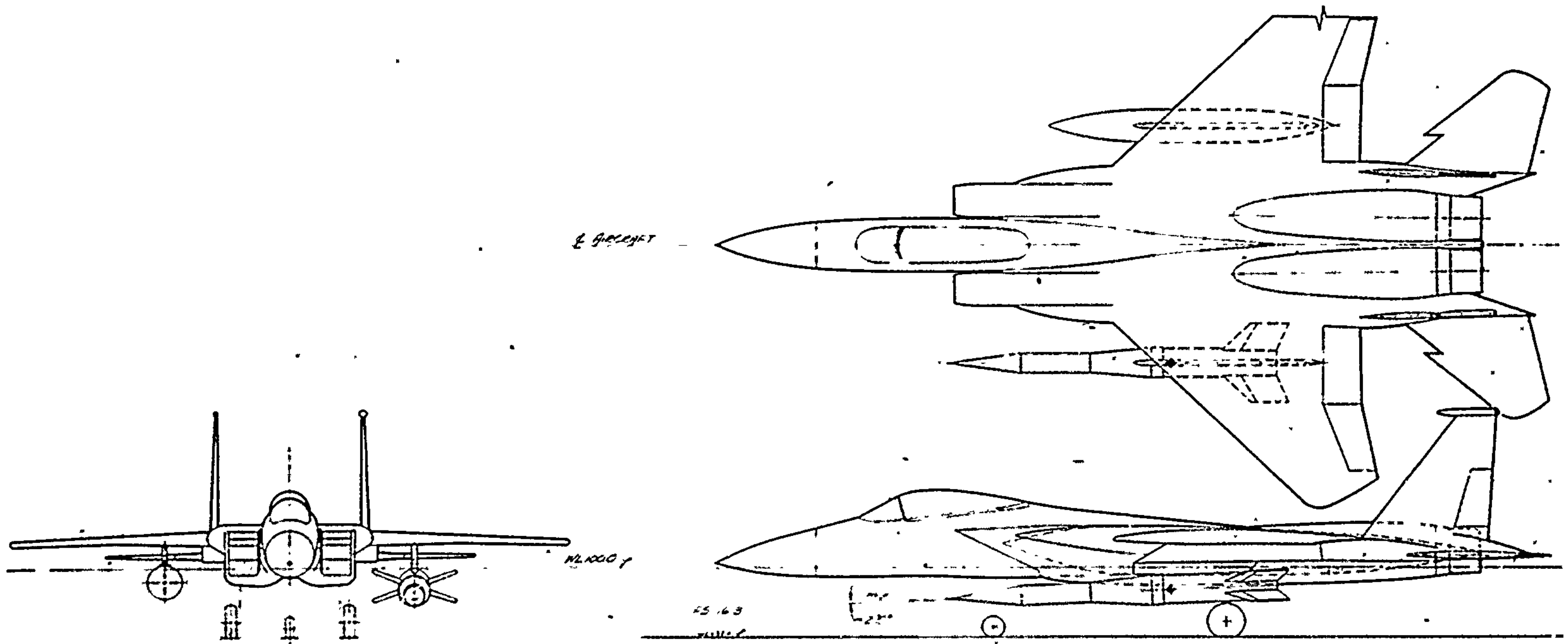

Figure D-1.   F-15 Aircraft/SUPER Flame Configuration

III, A, General (cont.)

Figure D-2 identifies the Super FLAME vehicle configuration. The long conical section extending forward on the second-stage motor consists of the interstage structure and a conical skirt for low drag. In addition, it provides flare stabilization during second-stage burn.

Figure D-3 is the Super FLAME main assembly. The baseline is seen with the 15 in. base diameter payload configuration.

The following lists some of the design features of the Super FLAME vehicle:

- Aft lug can be ejected.
- Greater first-stage stability.
- Stiffer, stronger second stage.
- Cleaner profile (11-1/2° interstage eliminated).
- Integral structure/nozzle concept saves weight.
- Performance less weight sensitive.
- Shorter burn time increases reentry angle capability.
- Electrical pull-away on cylindrical section.
- Larger payload volume.
- Readily adaptable to variety of missions.
- Potential third stage for probe missions.
- Payload separates from second stage, using an optimized, totally internal system that does not require a drag-inducing feature.

Table D-1 and Figure D-4 present the vehicle weights summary and stability margin.

B. VEHICLE SELECTION

An extensive trade-off study was performed in an attempt to optimize the Super FLAME vehicle. The elements involved included launch mode selection, as well as rocket performance.

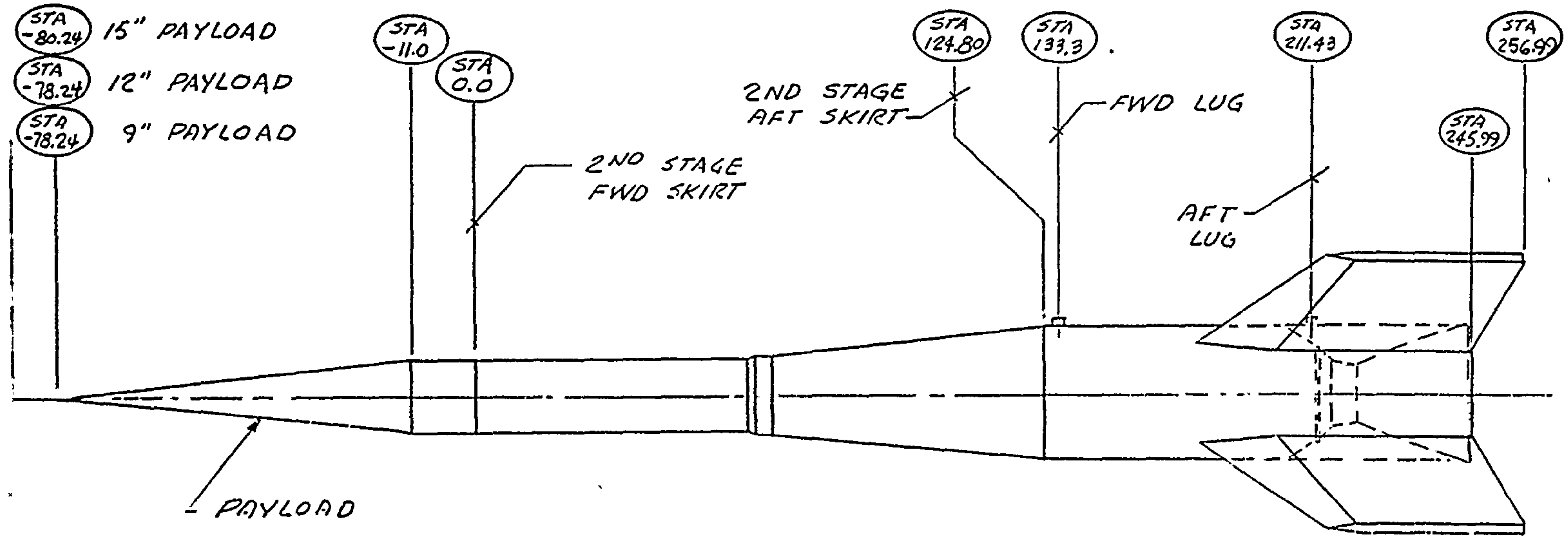

Figure D-2. Super FLAME Station Diagram

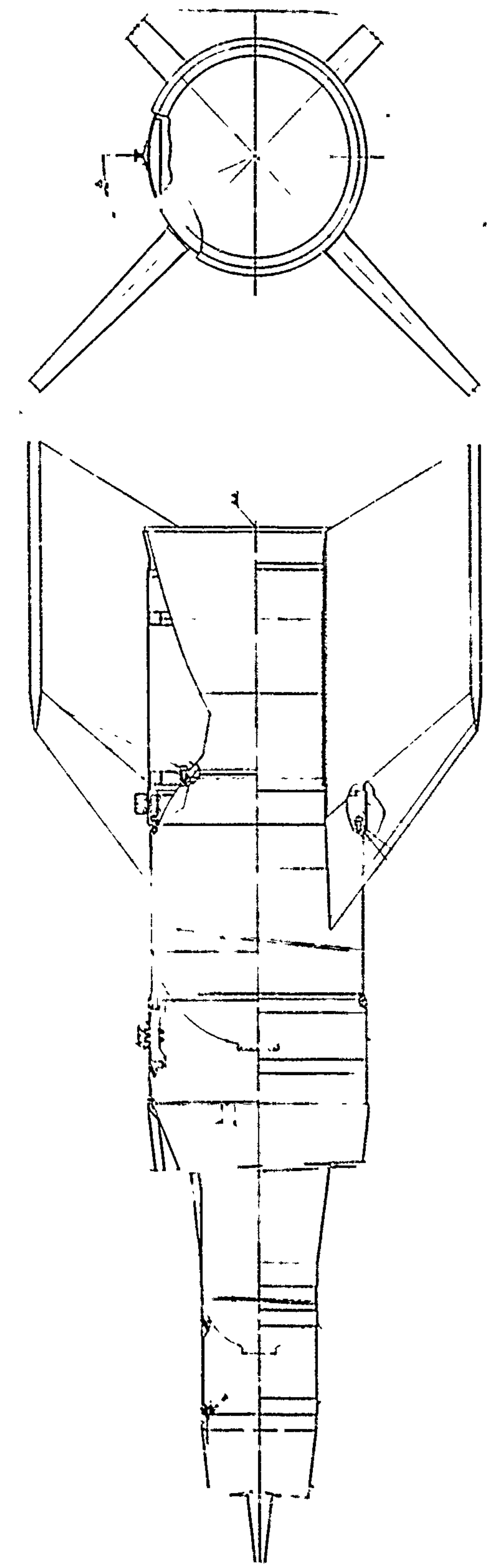

Figure D-3. Super FLAME Assembly

TABLE D-I

WEIGHTS SUMMARY

		Loaded Weight
1.	Payload	0.0
2.	Separation Mechanism	9.3
3.	Conical Skirt	12.92
	Insulation Cone	9.8
	Insulation Tension Joint	1.1
		23.82
4.	Electronics	2.0
5.	Second-Stage Motor Assembly:	
	Motor	1078.2
	Flare	44.7
	Insulation	12.0
		1124.9
	Second-Stage Totals	1160.0
6.	Separation Diaphragm	19.0
7.	Adapter	7.0
8.	Extension	20.0
9.	Electronics	6.0
10.	Motor TX-261-3 Mod.	3323.4
	Insulation	31.0
		3354.4
11.	Tail Structure	41.6
	Insulation	19.0
		60.6
12.	Fins	220.0
	First-Stage Totals	3687.0
	Vehicle Total	4847.0

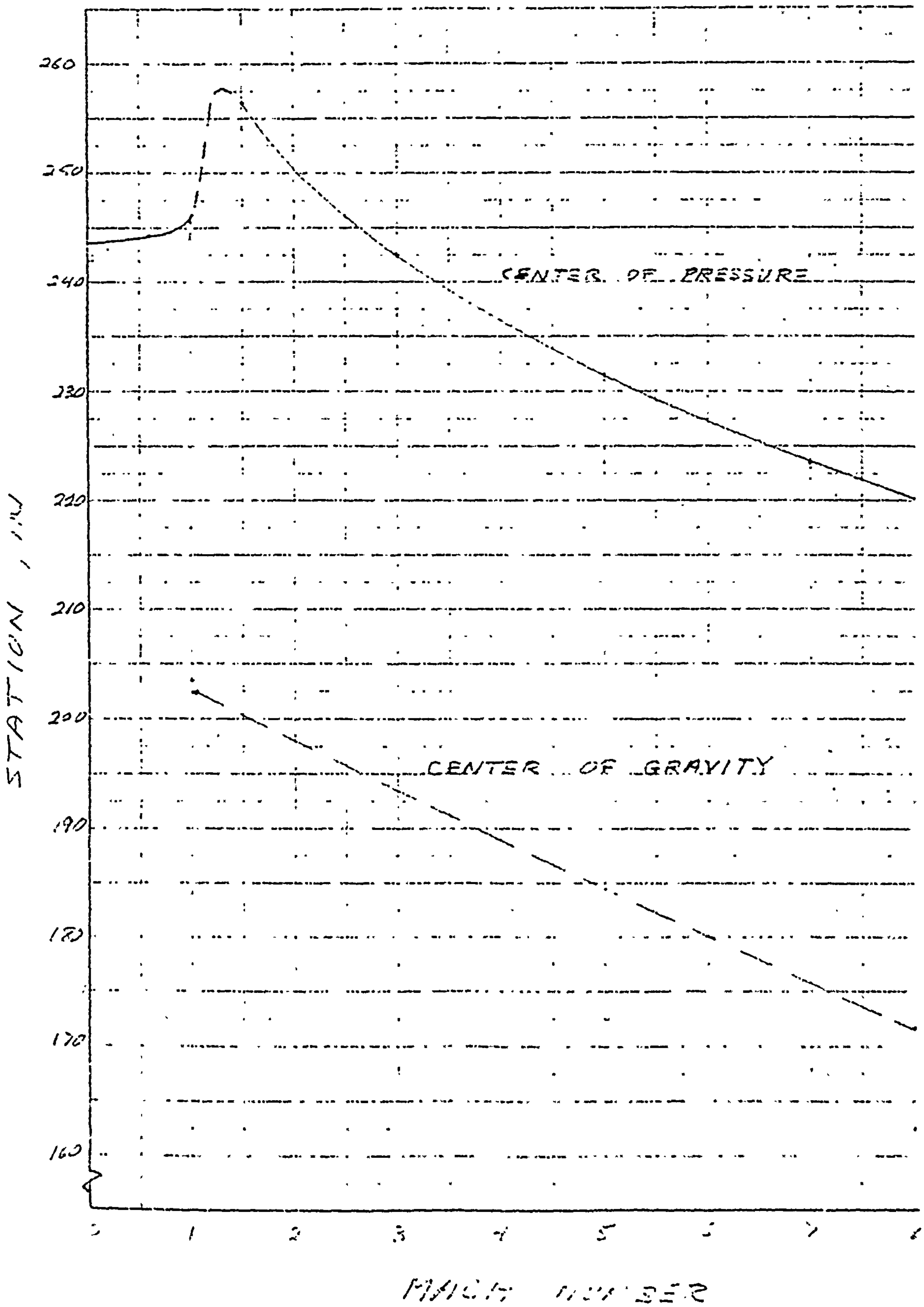

Figure D-4. Super FLAME Stability

The launch mode study investigated ground launch, aircraft launch, and high-altitude balloon platform launches. The aircraft examined included the F-4, F-101, F-111, F-14, F-15, B-58, and the B-52. The balloon platform and ground launches were ruled out because of the quick reaction, versatility, and low cost requirements dictated by the program.

1. Aircraft

Those elements examined in aircraft selection included performance, stores weight, and envelope capability, availability, and economics. The B-58 was ruled out because of availability and economics (costs associated with upgrading and maintaining an aircraft no longer in current service). The B-52 and F-101 cannot deliver the performance required; the B-52 from an altitude/velocity standpoint (internally carried), and the F-101 from an altitude/velocity standpoint (externally carried). In addition, the F-101 was structurally questionable. The F-14 lacked the capability of externally mounting a large store such as Super FLAME. The F-4 (used for the FLAME vehicle) is adequate, performance-wise, but lacks the envelope capability. The F-111 is structurally adequate; however, it lacks the desired performance with the increased payload.

The F-15 provides the structural, envelope, and performance capabilities desired. This fact has been verified by McDonnell-Douglas.

The performance capabilities of the Super FLAME vehicle, therefore, are presented using the F-15 aircraft for delivery.

The F-15 aircraft provides excellent performance capabilities in altitude, velocity, and gamma (55,000 ft, Mach 1.3, +30° gamma) with power to spare. Additionally, it provides sufficient stores envelope under the inboard wing pylon. The stores attachment is identical to FLAME, thus maximum use of existing hardware can be realized (Figure D-1).

2. Rocket Vehicle

The following elements were examined in selection of the final Super FLAME vehicle configuration:

a. Must be aircraft launched (F-15) and would simulate reentry trajectories for a payload of 75 lb. The vehicle flight profile was to maximize velocity at burn-out at 35,000 ft altitude at a flight path angle of -15 degrees or greater.

b. Must meet aircraft constraints in:

(1) Allowable weight
(2) Center of gravity
(3) Length
(4) Ground clearance
(5) Launcher mechanical and electrical compatibility
(6) Acceptable air flow interference
(7) Propellant classification acceptable for aircraft usage

c. Must have relatively short burn time (45 sec total, including coast period, and less than 4 sec for final stage burn) to reach acceptable reentry angle and minimize loss due to drag impulse.

d. All stages must have short thrust tail-offs.

e. The motor mass fractions must be high-- .75+.

f. Must have adequate motor case stiffness for flight endurance.

g. Aerodynamic stability is required during all stages of flight. The final stage must be flare stabilized as fin aero loading and heating would be too high and the force coefficient too low.

h. The ultimate configuration must be cost effective and utilize existing hardware and designs to the greatest extent reasonable.

i. It must withstand the temperature (low and high), acceleration, and spin environments to which it would be subjected.

The following configurations were examined as potential candidates with the inherent problems associated with each:

Configuration	Problem
Single-Stage:	Velocity too low
Two-Stage:	
Pedro/Recruit	Performance
Pedro/Sprint	2nd stage stability
Pedro/3 Recruits	Stage 2 structure, stability, performance
Pedro/Super FLAME 2nd Stage	Performance
Super FLAME	Acceptable
Sprint 2/Recruit	Performance
Sam D/Recruit	Performance.
Sprint 1/Sprint 2	Weight, diameter, stability, cost
Sprint 1/Super FLAME	Weight, diameter, stability, cost

Three-Stage:

The problems of length, motor burn time, and stability are more severe than for the two-stage because of the extra motor.

The final stage motor weight must be at least 4 times the weight of the payload to achieve a significant ΔV. The net ΔV of a motor the same size as the payload is close to 0 (could lose velocity).

C. VEHICLE DESCRIPTION

1. First Stage

The first stage consists of the motor, the tail structure with fins, the mounting lugs, and the forward transition section. The electronics associated with coast, first-stage burn, and second stage initiation are mounted in the forward transition section.

The Super FLAME vehicle tail structure is considerably lighter and simpler than that of the FLAME vehicle because the fin rotation system is eliminated. The rotating ring housings have been replaced with channels. Also, as can be seen in Figure D-5, the motor/can structure interface ring is now an integral part of the tail structure. A block is required under the aft lug (see Figure D-6) to distribute loads into the structure.

The fins will be those fins as used on FLAME. The fin area required is slightly less than FLAME; however, changing the existing tooling may not be cost effective for the slight performance improvement attained.

The first-stage motor will utilize the existing Pedro case (TX-261-3 or -5) and be loaded with a higher performance propellant (HTPB).

The current nozzle design is applicable to the modified motor (H Pedro).

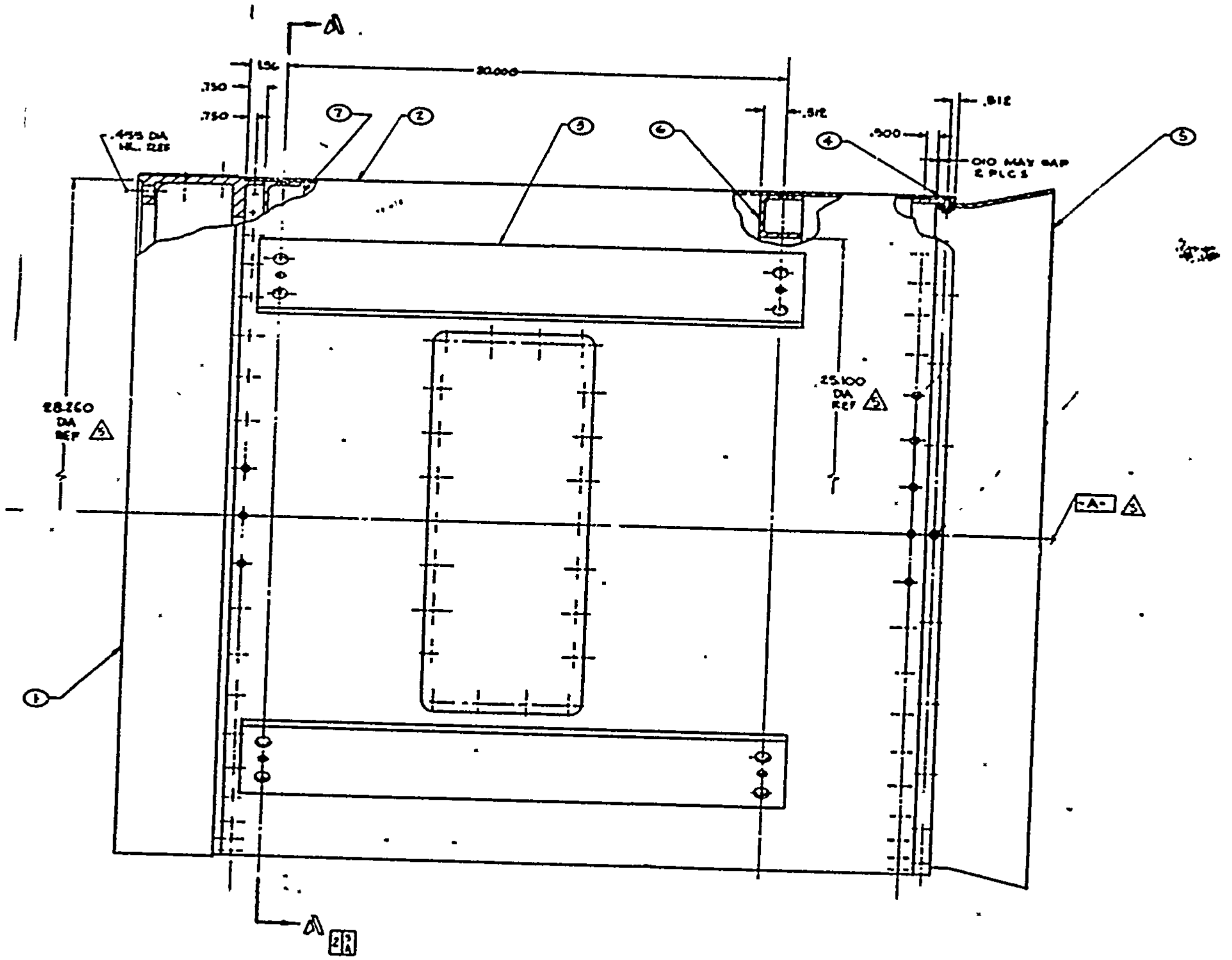

Figure D-5. Tail Structure Assembly

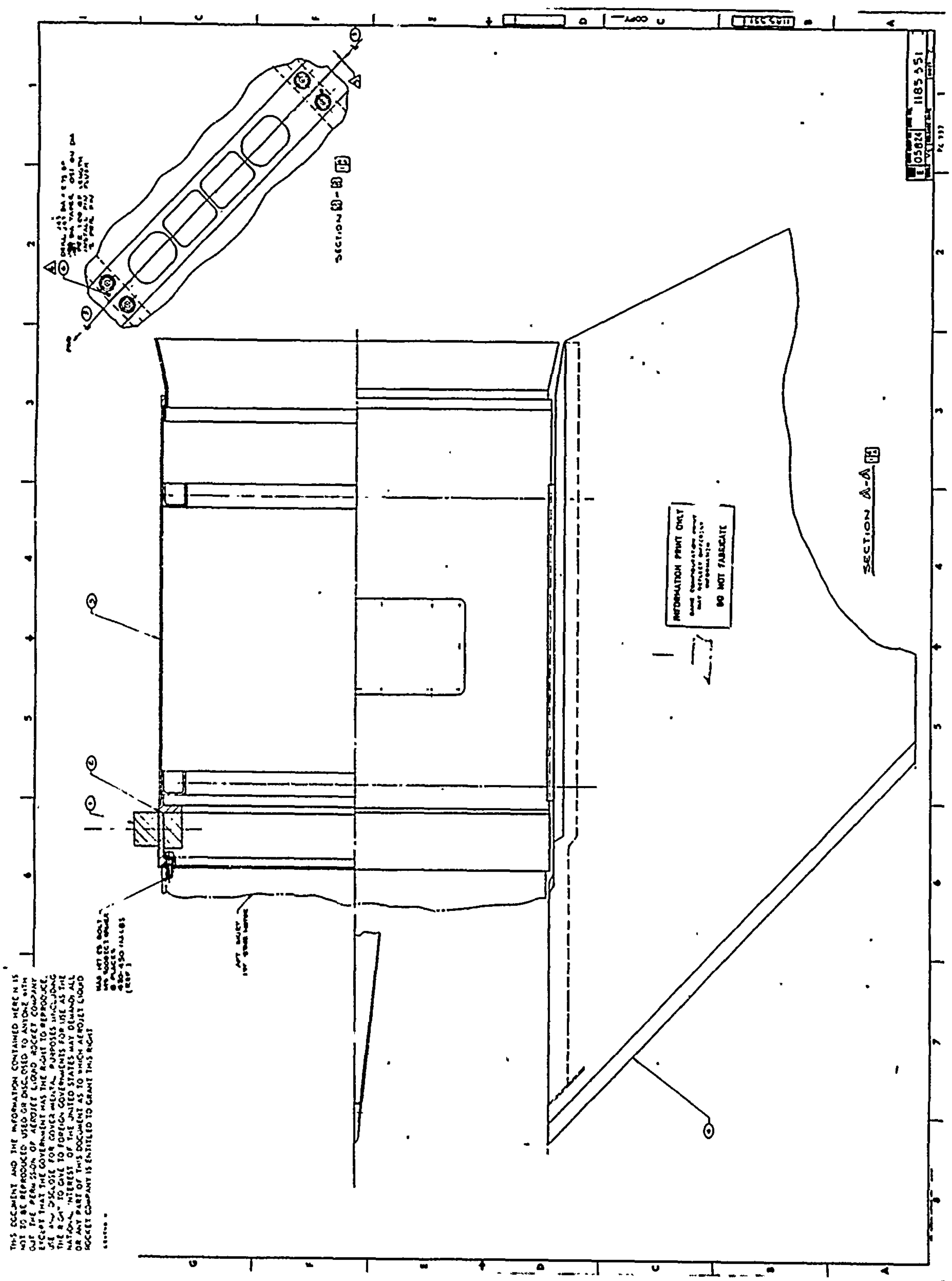

Figure D-6. Tail Structure

2. First-Stage Motor Description

The following is a description of a TX-261-3 motor modified to provide more performance for use on the Super FLAME vehicle. The present TX-261-3 hardware can be utilized as is; the only changes required are: (1) a new core configuration; (2) the addition of insulation inside the motor case; (3) a minor change to the nozzle throat diameter; and (4) incorporation of a different propellant

Figure D-7 is a layout drawing of the modified TX-261-3 motor and Table D-II summarizes its major characteristics. The propellant grain configuration is a cylindrical core coupled with five short longitudinal slots that extend downward and follow the aft-end case contour. Five additional "control" slots are used for tailoring the initial pressure and thrust characteristics. The forward section of the propellant configuration contains a stress relief "groove." The 70% web fraction depicted on the layout drawing was calculated to withstand the pressures and temperature conditions that would be encountered.

The propellant used in the modified motor is an HTPB composition developed for the Air Force and is fully characterized. It has a burning rate at 1,000 psia of approximately 1.3 in./sec and is an 88% solids propellant with 17% aluminum, 2% iron oxide, 3% DOA, and 69% ammonium perchlorate.

a. Performance

Figure D-8 depicts the pressure and thrust characteristics of the proposed design. The initial conditions are controlled through the influence of the five small longitudinal slots. The "bottoming out" of the curves at approximately 5.5 sec is due to the propellant controlled by the five longitudinal slots being consumed. Figure D-8 also shows the maximum pressure and thrust peaks occurring at the end of web time. It is to be

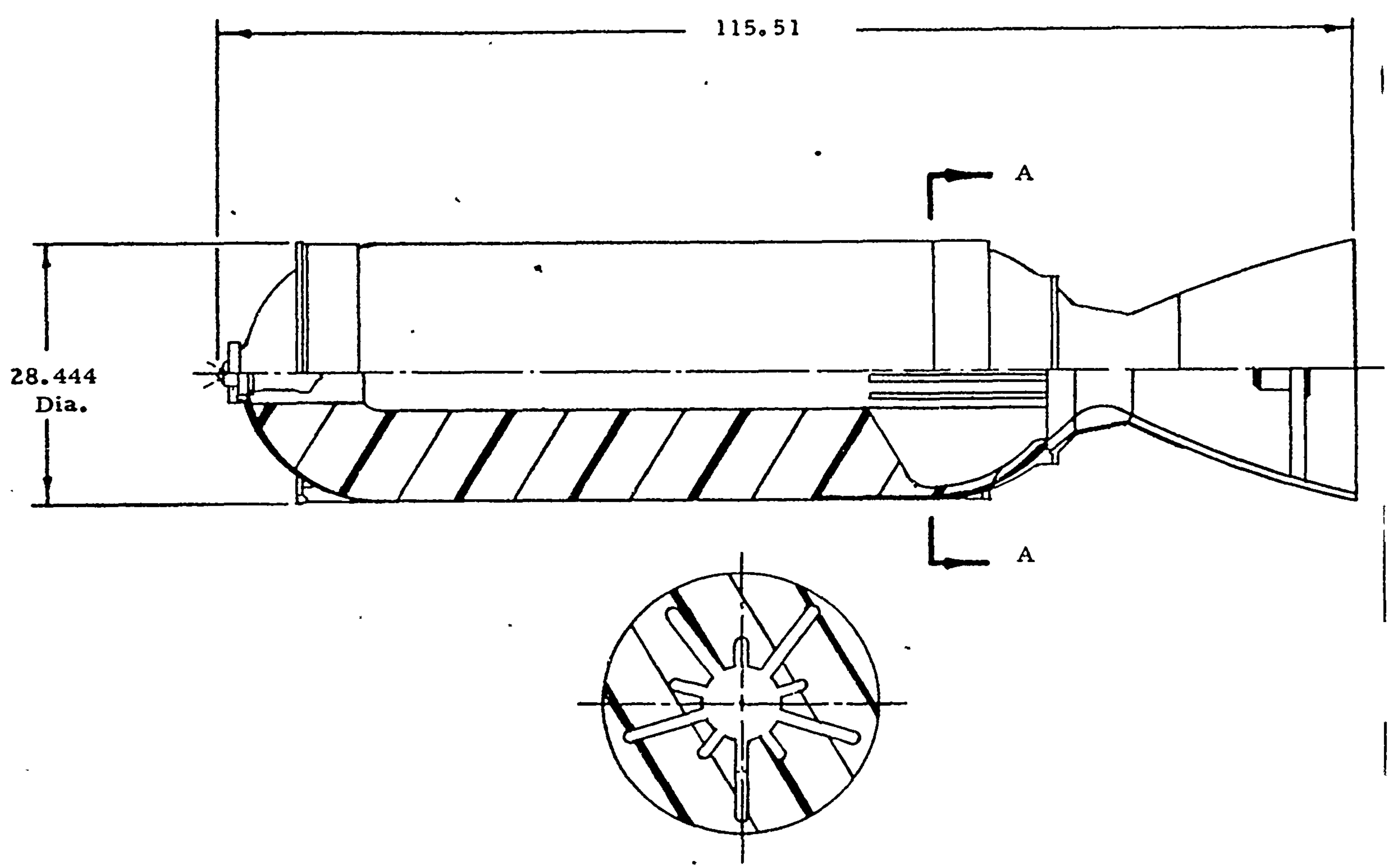

Figure D-7. Modified TX-261-3 Motor Assembly

TABLE D-II

MOTOR PERFORMANCE PARAMETERS
(at Sea Level and 70°F)

	Modified TX261-3	TX261-3
Web Burning Time, sec	9.37	9.01
Average Thrust, lb	63,775	56,030
Average Pressure, psia	705	705
Total Impulse, lb-sec	597,600	540,300
Total Impulse/Total Weight, lb-sec/lb	193.0	188.5
Propellant Weight/Total Weight	0.81	0.81

GENERAL SPECIFICATIONS

	Modified TX261-3	TX261-3
Dimensions, in		
Overall Length	115.51	118.96
Outside Diameter	28.44	28.44
Weights, lb		
Propellant	2,514	2,323
Chamber	357	357
Nozzle Assembly	123	123
Liner and Insulation	80	40
Igniter (Pyrogen)	14	14
Miscellaneous Components	9	9
Total Weight	3,097	2,866
Propellant Geometrical Parameters		
Volumetric Loading Density, %	88.4	84.0
Web Fraction, %	70.0	42.6
Geometrical Web Thickness, in	9.7	5.906

TABLE D-II (cont.)
MOTOR PERFORMANCE PARAMETERS
(at Sea Level and 70°F)

	Modified TX261-3		TX261-3
Nozzle			
Geometry			
Type		Fixed	
Expansion Section Configuration		Conical	
Number of Nozzles		One	
Throat Diameter, in (initial)	8.784		8.406
Exit Diameter, in (initial)		28.15	
Throat Area, in^2 (average)	60.72		55.60
Expansion Ratio (average)	10.24		11.19

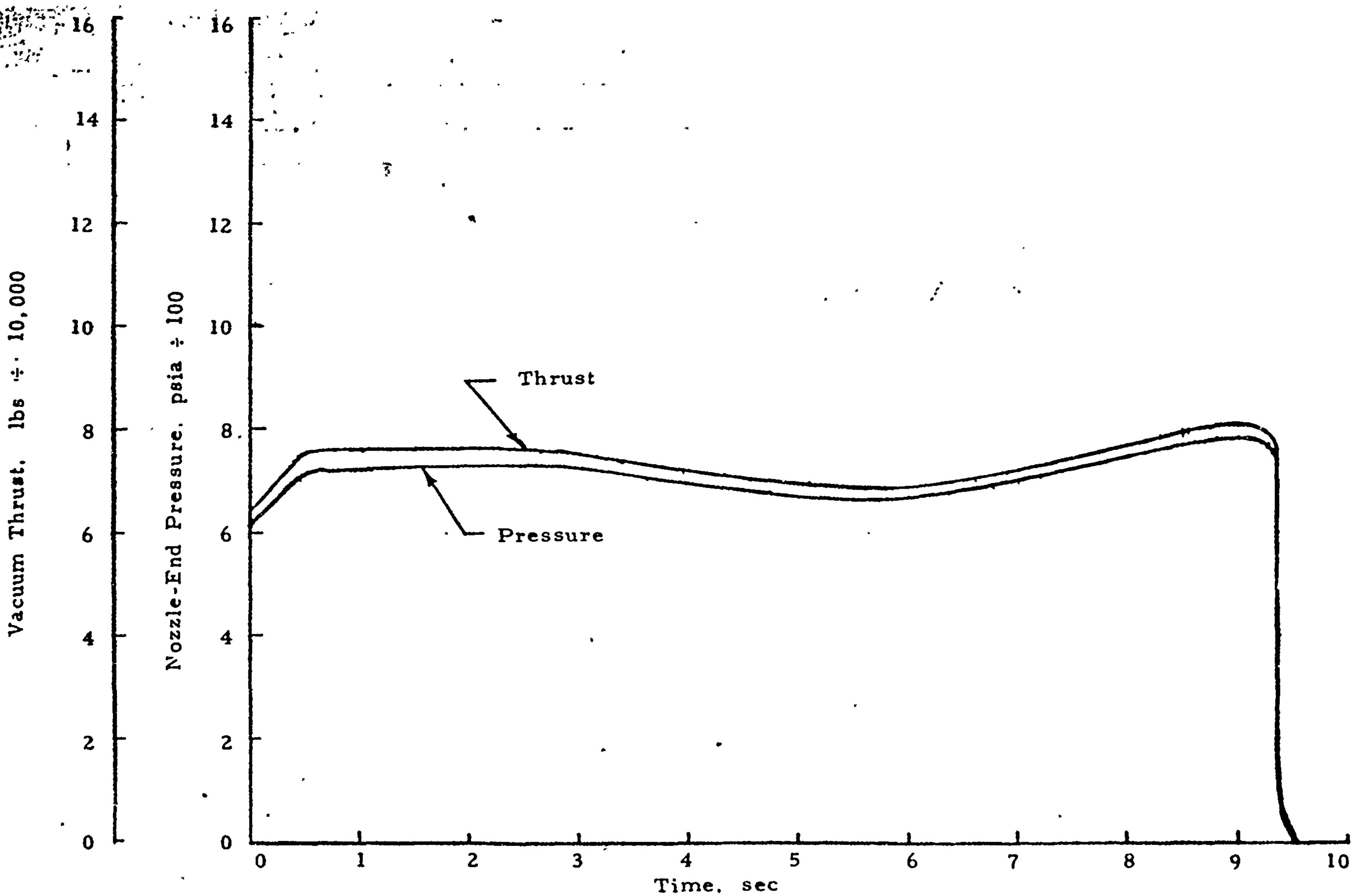

Figure D-8. Typical Thrust/Pressure vs. Time Curves (Modified TX-261-3) noted that these peaks can be readily controlled by increasing or decreasing the length of the longitudinal slot section.

b. Parametric Performance Study

Figure D-9 gives a parametric study utilizing the proposed propellant configuration, maintaining constant pressure, exit diameter and burning rate, but varying the web thickness, thereby reducing the web time total impulse and propellant weight.

Figure D-10 shows results of another study that involves the proposed propellant configuration where the web thickness, exit diameter, propellant weight, and burning rate at 1,000 psia are held as constants and the pressure is varied. The purpose of this study is to point out the increase in performance that can be realized by increasing the pressure. The present TX-261-3 motor case is made from 4130 steel, has a minimum yield strength of 145,000 psi, and has a nominal wall thickness of 0.11 in. Although the proposed modified TX-261-3 operates at the present TX-261-3 average chamber pressure, the chamber can withstand pressures if reduced safety factors are acceptable.

A comparison of the performance parameters between the present TX-261-3 motor and the proposed modified TX-261-3 is included in Table D-III.

3. Interstage

The first-stage forward skirt attaches to an adapter ring at the forward end of the motor, using a tension joint. The forward end of the skirt provides the separation joint (using a separation diaphragm with Acme threads as in the FLAME vehicle design.

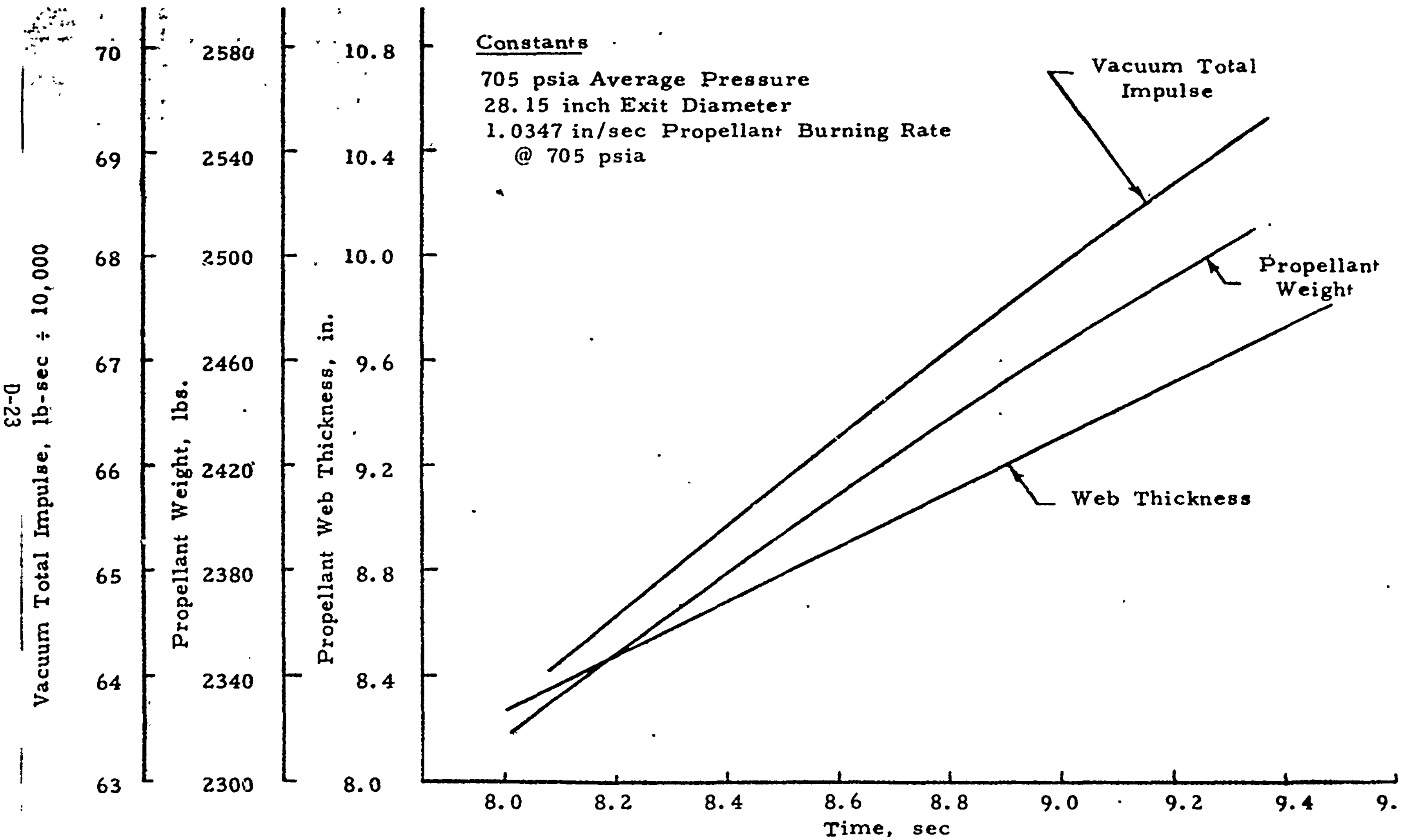

Figure D-9. Motor Characteristics vs. Time (Modified TX-261-3)

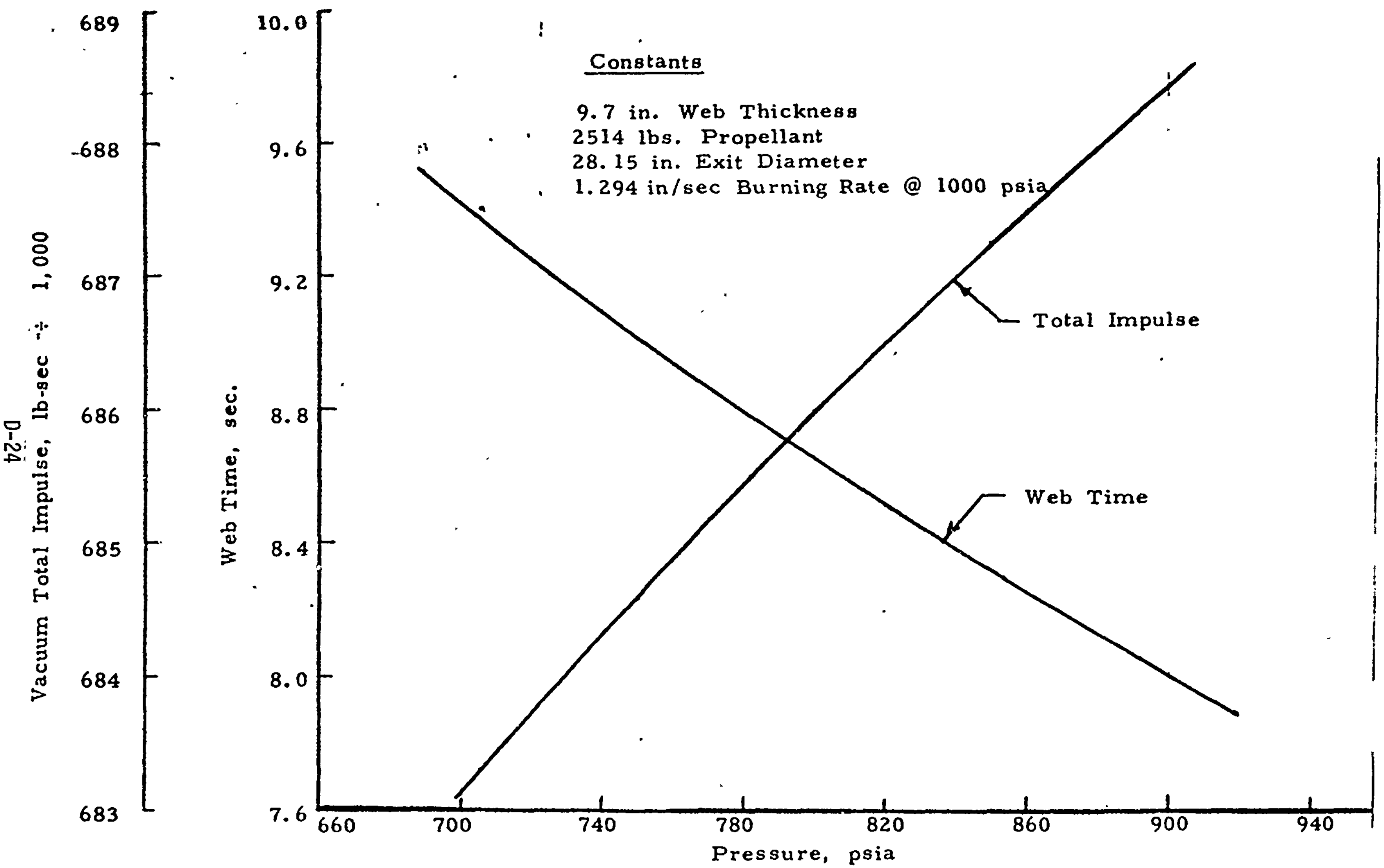

Figure D-10. Total Impulse Curves (Modified TX-261-3)

TABLE D-III

COMPARISON OF BALLISTICS FOR TX261-3 AND MODIFIED TX261-3 MOTORS (at Sea Level and Vacuum)

	Modified TX261-3	TX261-3
Average Thrust, lb (Sea Level)		
20°F	58,170	49,830
70°F	63,770	56,030
120°F	69,850	62,980
Average Pressure, psia		
20°F	651	635
70°F	705	705
120°F	764	780
Web Burning Time, sec		
20°F	10.10	9.96
70°F	9.37	9.01
120°F	8.69	8.17
Total Impulse, lb-sec/lb (Vacuum)		
20°F	679,900	636,700
70°F	683,300	638,400
120°F	686,700	639,800
Total Impulse, lb-sec (Sea Level		
20°F	587,490	529,900
70°F	597,570	540,300
120°F	607,190	550,330

For Modified TX261-3 Only.

Assumed Average Thrust Efficiency Factor, C_m = 0.962

Divergence Loss Factor, λ_N = 0.983

As can be seen in Figure D-11, the, the skirt has a 7° half-angle and is of the same construction as the FLAME vehicle. Brackets can be mounted within the skirt for electronic component mounting as well as antennas.

4. Second-Stage Motor Description

The second stage consists of a short burn, high mass fraction motor with structural nozzle, forward skirt, and payload interface. The second stage ignites upon first-stage chamber pressure decay and burns for approximately 2 sec. A typical motor configuration is shown in Figure D-12. Second-stage pressure decay initiates payload separation.

The motor nozzle provides the structure between the motor case and first/second-stage interface. The interface details can be seen in Figure D-13. The forward joint on the motor is a tension joint, providing the bending strength required without external protrusions.

The second-stage motor specification follows:

Super FLAME Second-Stage Propulsion Module

1. Lengths

a.	Parting Line-to-Parting Line, in.	124.00
b.	Igniter Boss Face to Nozzle Exit Plane, in.	127.75

2. Diameters

a.	Motor Case Metal O.D., in.	15.00
b.	Motor Case Exterior Insulation O.D., in.	15.20
c.	Nozzle Throat, Initial, in.	8.71
d.	Nozzle Exit I.D., in.	27.07
e.	Nozzle Exit, Metal, O.D. of Stage Coupling Ring, in.	28.75
f.	Nozzle Exit, Exterior Insulation O.D., in.	29.00

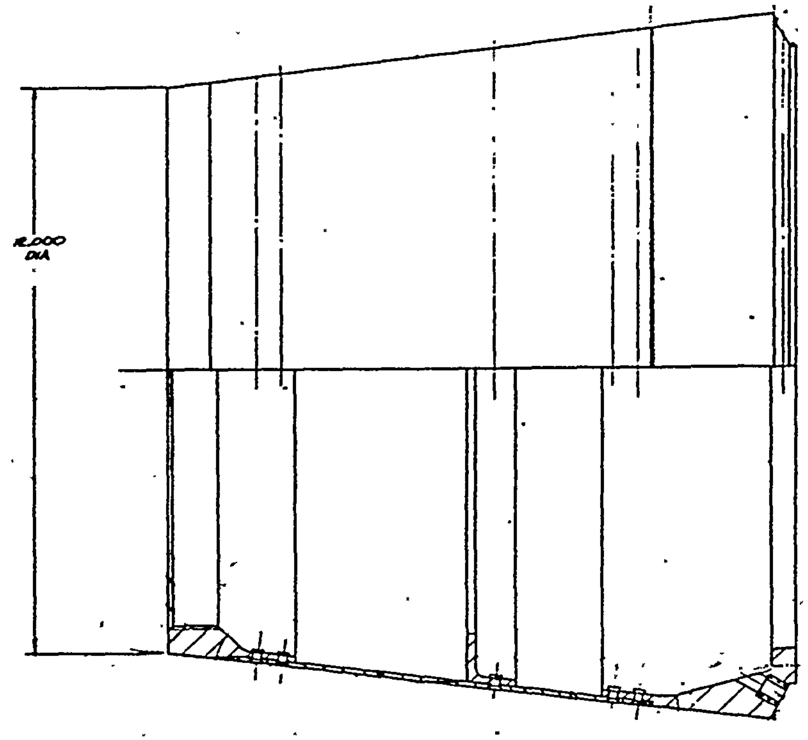

Figure D-11. First Stage Forward Skirt

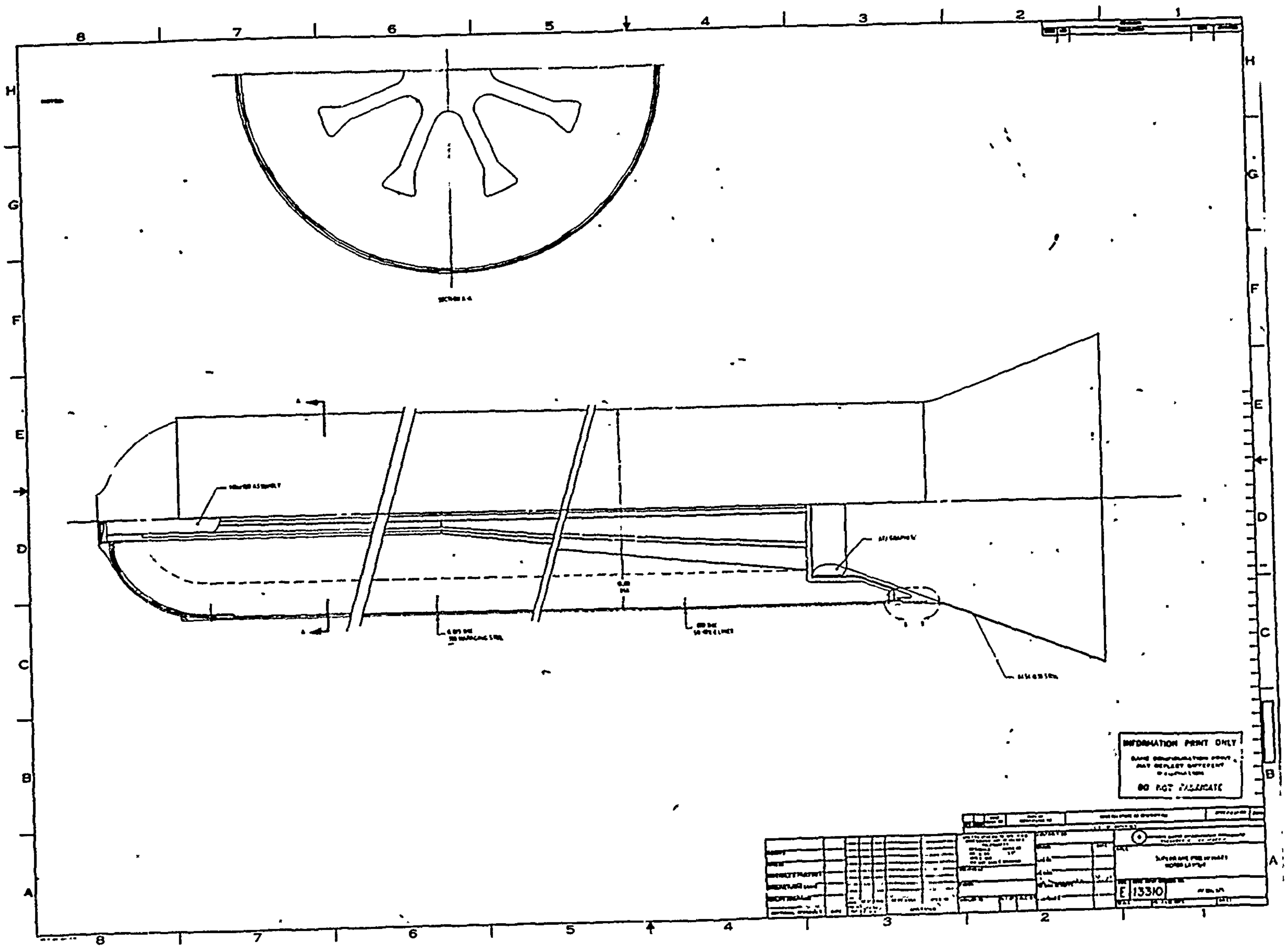

Figure D-12. Super FLAME Preliminary Motor Layout

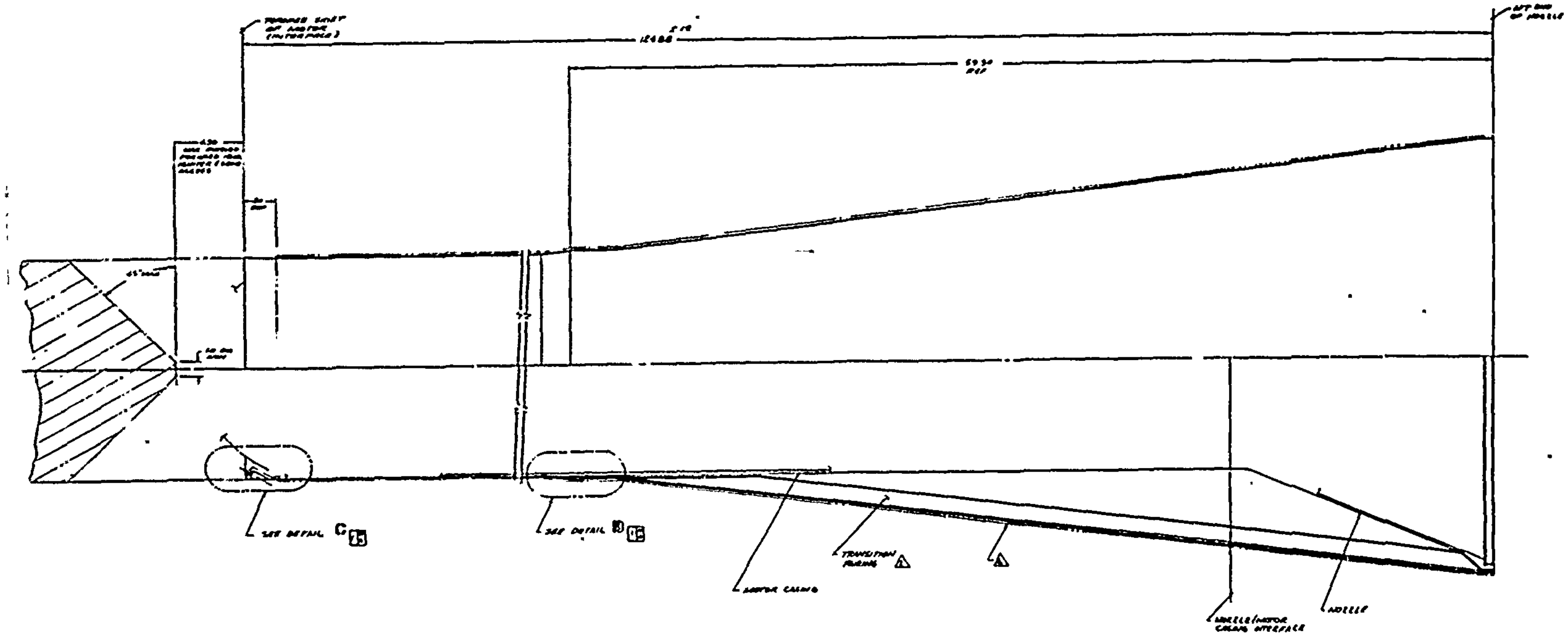

Figure D-13. Motor Assembly/Transition Faring - Super FLAME Second Stage

3. Weights

a.	Motor Case, Metal, lb	121.0
b.	Motor Case, Exterior Insulation, lb	21.2
c.	Motor Case, Interior Insulation, lb	12.0
d.	Nozzle, Less Stage Adaption Ring, lb	57.6
e.	Stage Adaption Ring, lb	3.9
f.	Aft Flare Assembly, lb	55.0
g.	Igniter Assembly (Propellant Type), lb	7.0
h.	Forward Tension Joint Ring, lb	3.4
i.	Propellant, lb	920.0
j.	Initial Weight, lb	1201.1
k.	Weight Loss During Burn, lb	930.5
l.	Final Weight, lb	270.6

4. Propulsive Performance, -20°F @ Vacuum, Nominal

a.	Total Impulse Delivered, lb_f-sec	240,000
b.	Propellant Specific Impulse, sec	263.00
c.	Total Burn Time, sec	2.10
d.	Action Time, sec	1.90
e.	Thrust Curve Neutral to Progressive	-
f.	Total Impulse Delivered During Action Time, lb_f-sec	240,000
g.	Maximum Total Impulse Delivered After 10% T_{max} tail-off, lb_f-sec	1,159

The second-stage motor assembly is illustrated in Figure D-13. A fiberglass honeycomb flare protects the stage thermally. Fiberglass is used exclusively on the second stage because of the thermal environment. FLAME used Firex; however, in the more severe thermal environment, fiberglass is superior from a weight standpoint.

5. Payload Interface

The forward skirt houses the ignition and payload separation electronics. Payload separation will be achieved differently than on the FLAME vehicle. The payload will be attached using a separation diaphragm much like the one used in attaching the first and second stages. The advantages of this system include:

a. Positive separation (velocity increment imparted to payload by system).

b. Minimal tip-off.

c. System dynamics are adjustable to meet desires.

d. Provides superior joint.

e. Does not affect external aerodynamic body contour.

f. Is initiated by flight-proven ordnance.

g. The system is self-contained.

The separation system consists of a double-acting piston/cylinder that, upon being pressurized (by ordnance pressure cartridge), deflects the separation diaphragm to unlatch the payload. When the diaphragm deflects sufficiently, the system then reverses to drive an inner piston forward to positively drive the payload ahead of the spent stage.

The separation system requires minimal interface constraints with the payload. Figure D-14 is the proposed interface control drawing.

6. Flight Control

The Super FLAME vehicle will utilize an on-board attitude-sensitive ignition system. This system, being a derivative of components used in ALRC's sounding rocket attitude control systems, will eliminate those past problems as experienced on FLAME (command ignition problems because of radar drop-outs, computer problems, etc.). Additionally, it will reduce the errors associated with the desired flight path.

This is accomplished by an attitude detection system (ADS) which provides a means for initiating ignition of the Super FLAME first stage at a prescribed pitch-down attitude. The system includes a two-degree-of-freedom ("free") gyro oriented so as to obtain pitch attitude information from the inner gimbal synchro. Initial alignment of this gyro is achieved by hand-off from the aircraft obtained just prior to start of the 2-g climb (and thus approximately 30 seconds before drop of the FLAME vehicle). The ADS gyro thereafter provides a measure of pitch attitude departure from horizontal. The ADS monitors the pitch gimbal angle and provides an ignition-initiation signal when the pitch-down attitude exceeds approximately 12 degrees. This output from the ADS is gated by a sequencer-timer so that ignition cannot occur until at least 25 seconds after drop. Operation of the ADS is completely automatic. Its incorporation into the Super FLAME vehicle imposes no additional duties upon the aircraft pilot.

Initial alignment of the ADS gyro is accomplished by gyro caging circuits within the ADS. The outer (roll) gimbal alignment serves merely to hold the inner gimbal axis normal to the pitch plane. Accuracy is not critical and uncertainty of up to 5 degrees can be tolerated. Therefore, this alignment is effected simply by caging the outer gimbal to the

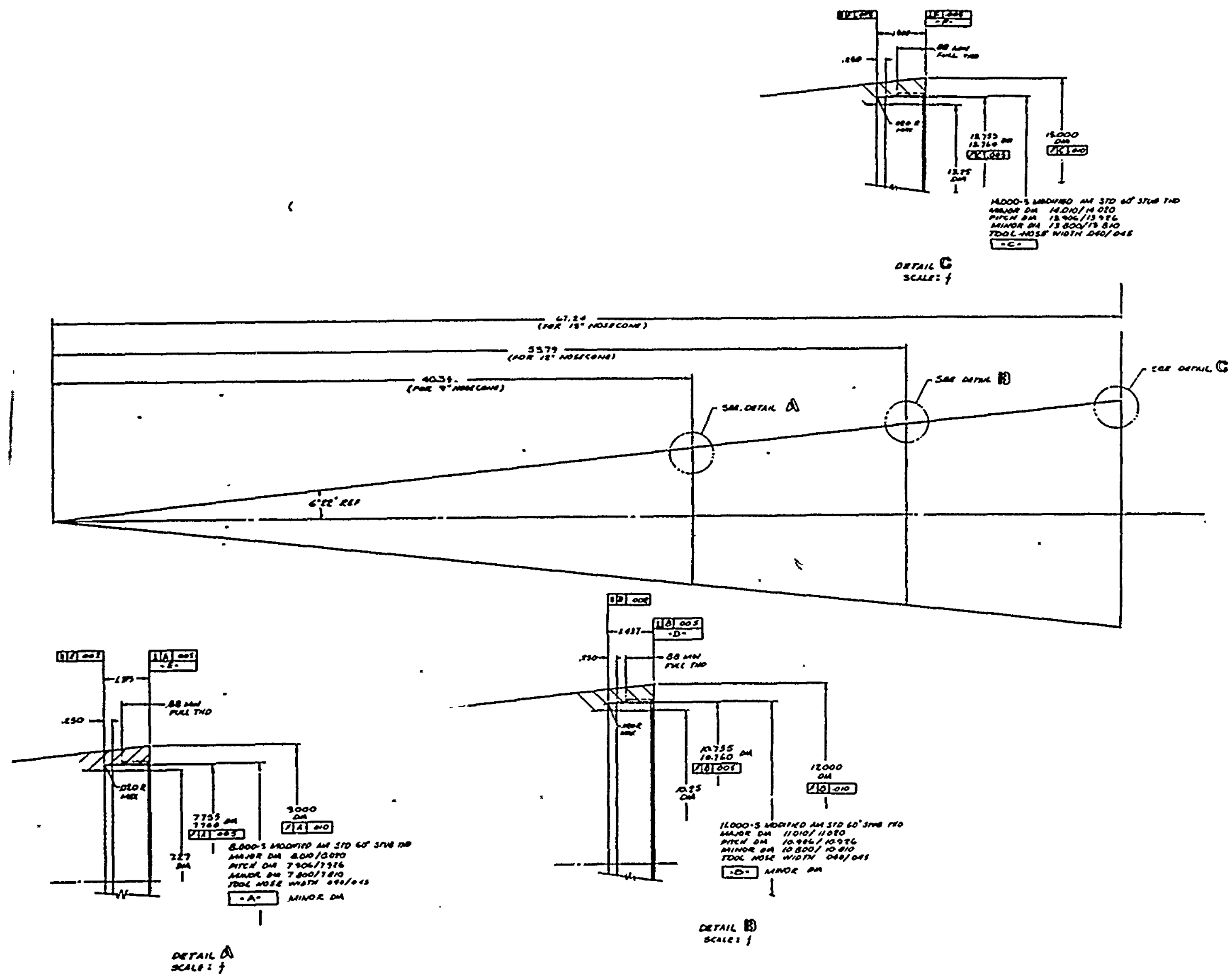

Figure D-14. Nosetip Interface

body. Its accuracy is thus dependent upon roll control of the aircraft by the pilot which is expected to be maintained within a few degrees. The ADS gyro inner gimbal is "slaved" to the aircraft vertical gyro. That is, the inner gimbal is made to follow the pitch gimbal of the aircraft gyro, exhibiting the same departure from horizontal. The caging and slaving process is continuous from aircraft takeoff. It is interrupted whenever the aircraft pitch-up attitude exceeds 4 degrees. The final interruption will occur when the aircraft enters the 2-g climb preceding vehicle drop. At drop, the caging/slaving circuits will be disabled and the gyro will operate inertially thereafter.

The ADS will initiate ignition at the desired pitch-down attitude within an accuracy of better than 1 degree. This estimate includes an error allotment of 0.5 degrees for the aircraft vertical gyro. Pitch angle detection will be compensated for predictable spin-induced drift by appropriate adjustment of the pitch-down attitude detection level (nominally 12 degrees). Noncompensatable drift, spin rate uncertainty, level detection tolerance, and caging deadband constitute other error sources allotted for.

The design approach is shown in the block diagram (Figure D-15). The free gyro has two independent axes which are separately controlled by cage control loops. The pitch loop keeps the ADS pitch gimbal angle equal to the aircraft vertical gyro angle when the cage loop is active. The roll loop holds the ADS roll angle at zero (corresponds to the body roll axis) when the cage loop is active. A positive four-degree detector keeps the caging loops active for angles less than plus four degrees. The caging loops are both disconnected when the pitch angle exceeds plus four degrees, and after the vehicle has been dropped from the aircraft (umbilical-pull lockout). A minus twelve-degree detector (or other setting) produces a first-stage motor ignition signal. The signal is logically gated with safe and arm control, a 25 sec inhibit (after release) signal, and a back-up ignition signal.

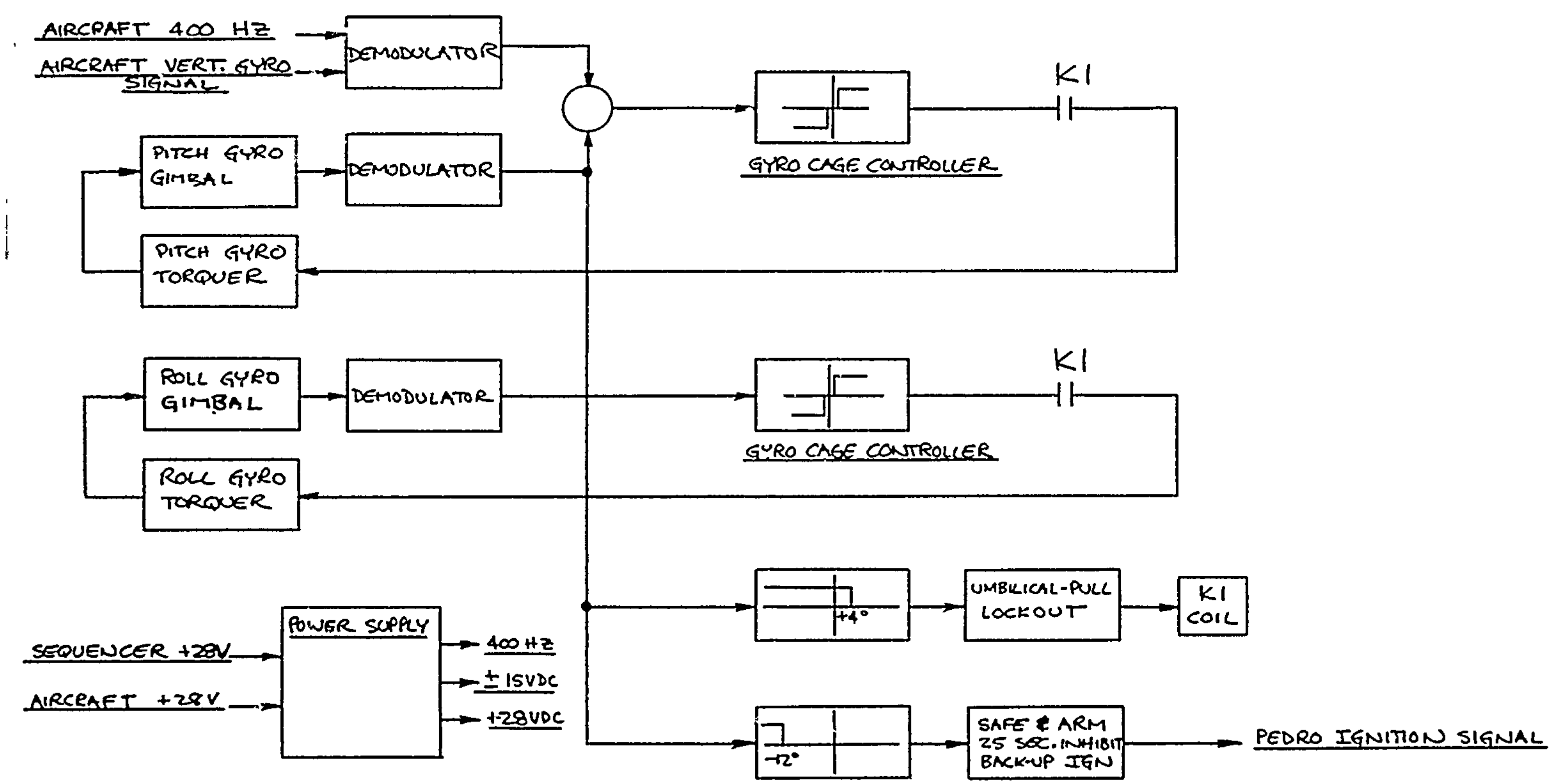

Figure D-15. Block Diagram - Attitude Detection System

The aircraft vertical gyro (pitch) signal is an AC signal supplied from the vertical gyro synchro. This signal is demodulated in the ADS using aircraft 400 Hz voltage for the demodulator reference. A variable amplitude, bipolar signal is obtained at the output of the demodulator. This is compared to an equivalent signal from the pitch gyro demodulator. The resultant error signal causes the pitch gyro to torque into alignment with the vertical gyro (error signal equals zero).

A power supply produces 400 Hz power to operate the gyro spin motors and synchros. Plus and minus 15-volt output power the electronic circuits in the demodulators, cage controllers, and plus 4 and minus 12 degree pitch angle detectors. The power input (+28 V DC) is supplied by the aircraft until drop. After drop, the sequencer battery supplies +28 V DC until motor ignition.

IV. PERFORMANCE

The Super FLAME vehicle performance, as discussed in this section, is for rain erosion missions. Super FLAME performance estimates for other applications appear in Section V. All data presented are relative to use of the F-15 as the launch aircraft.

Figure D-16 compares the Super FLAME against FLAME vehicle performance in altitude and velocity. Data are presented for payload weights of 75 and 100 lb. Note the relative velocity increase of 3800 fps is achieved using Super FLAME.

Figure D-17 illustrates Super FLAME performance capabilities in maximum velocity of various payload weights with altitude. The ANT curve is also presented for comparison.

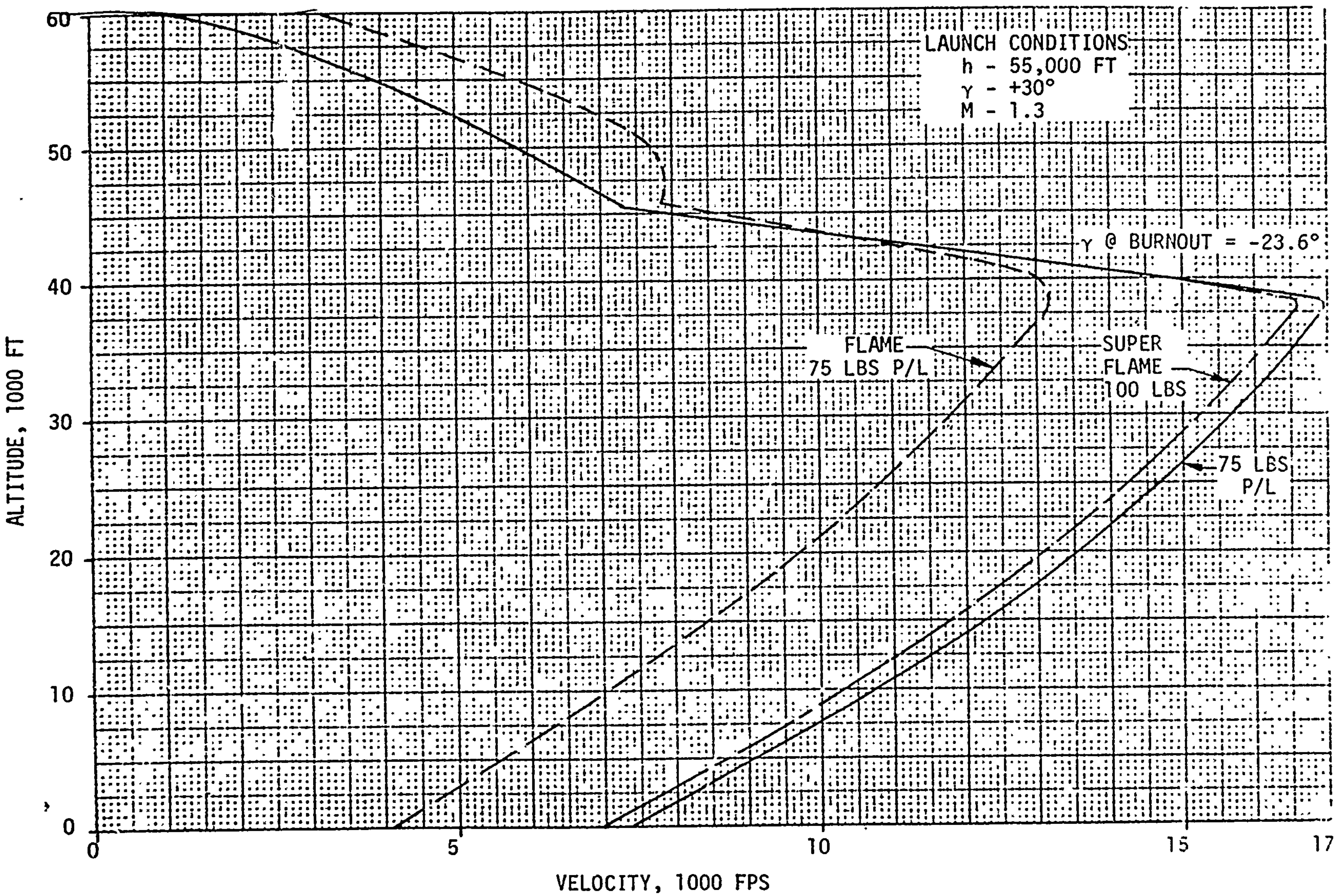

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Figure D-16. Super FLAME Velocity/Altitude Curves

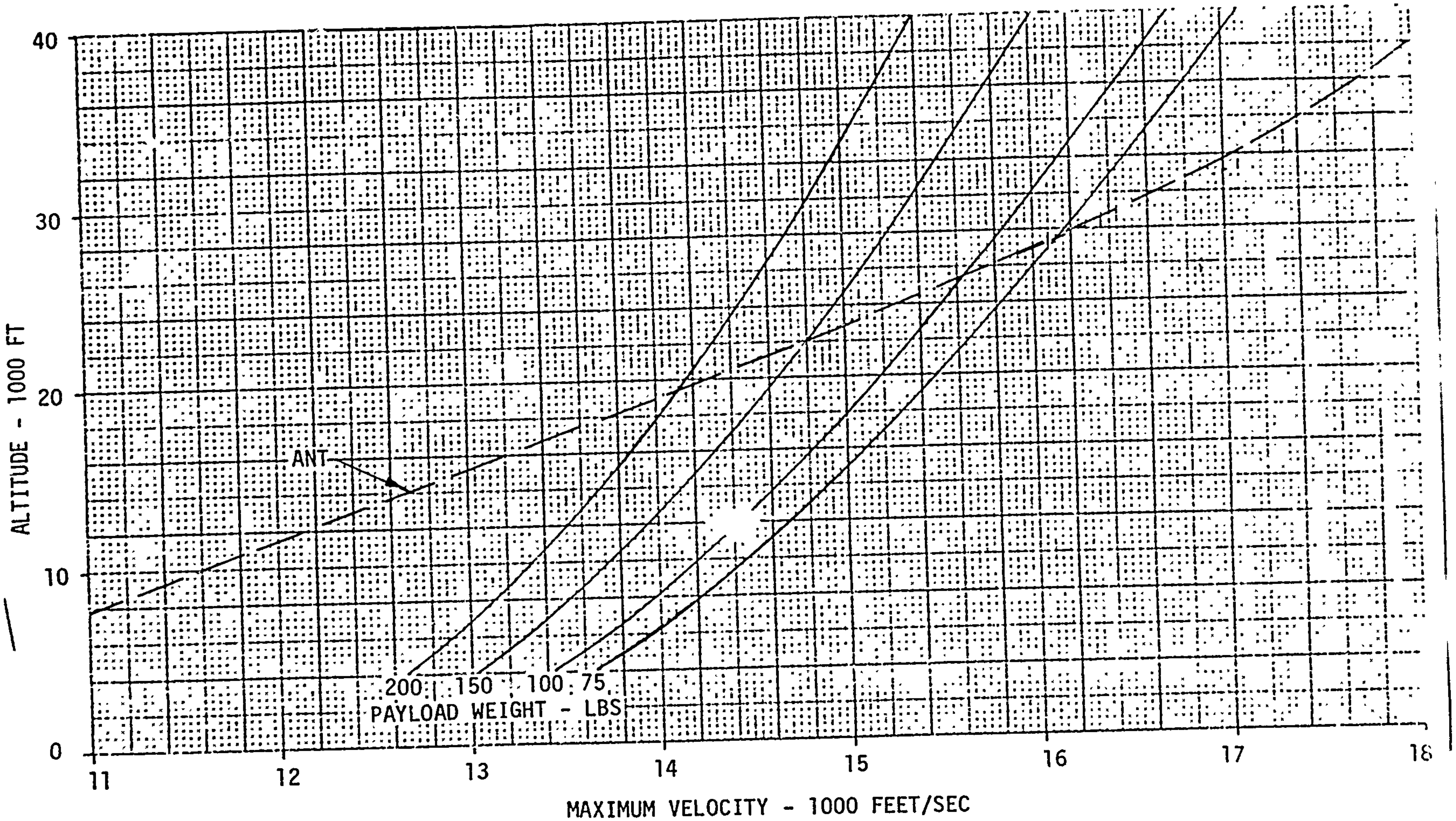

Figure D-17. Super FLAME Maximum Burnout Velocity vs. Altitude

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V. SUPER FLAME - OTHER MISSION APPLICATIONS

Because of the system's versatility in design, it can be used for a number of test vehicle applications.

Figure D-18 illustrates payload weight against maximum velocity for antenna/material testing and arm/fuse impact testing.

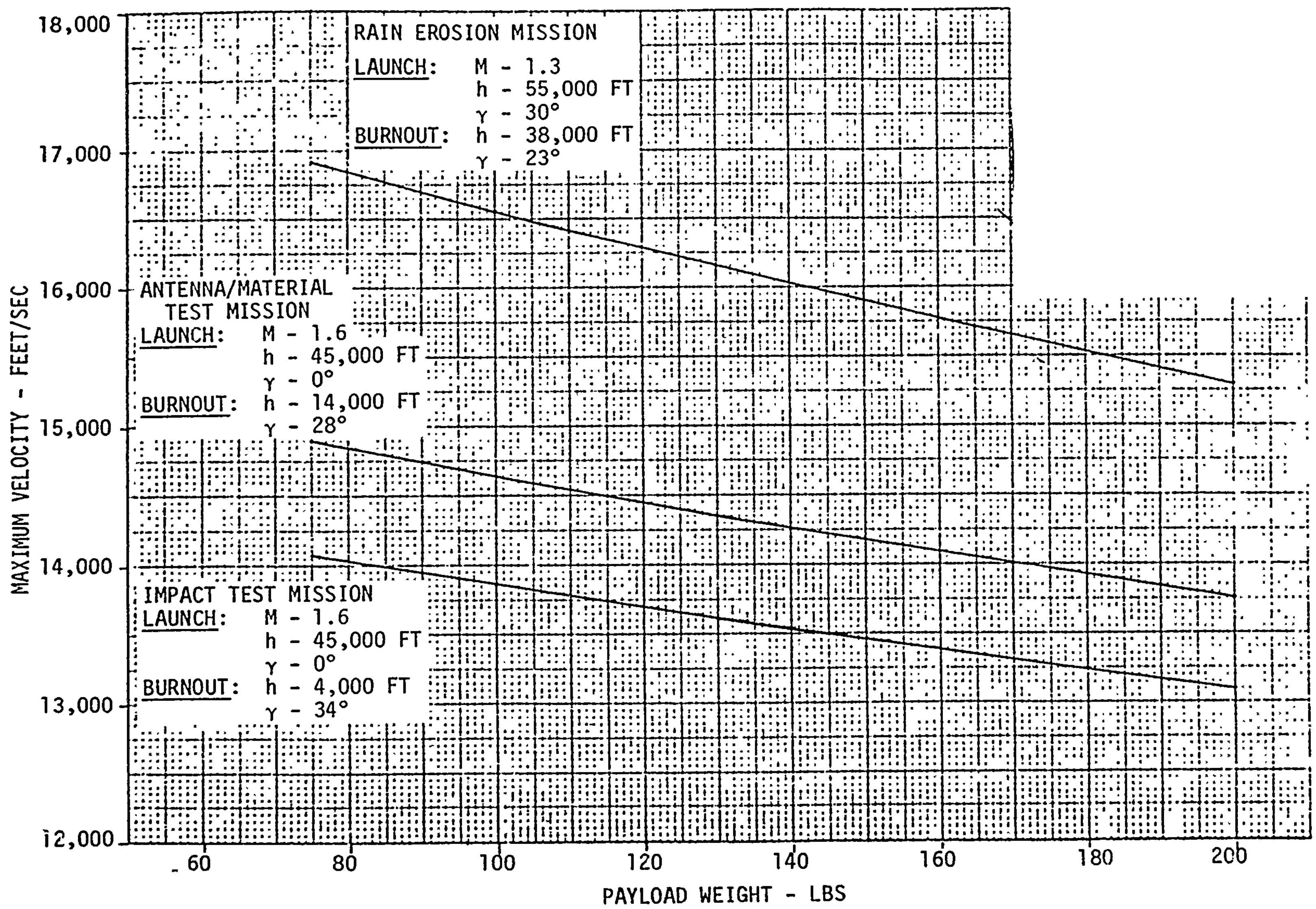

Figure D-18. Super FLAME Vehicle Performance - Other Applications

APPENDIX E

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APPENDIX E

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